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A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

The following letter dated August 9, 1928, was received

Correspondence *from Mr. William Campsie, manager, Hutchinson Sugar Plantation Company:*

In looking over the article on "The Degree of Resistance and Susceptibility of Seedlings to Eye Spot" in last *Planters' Record*, we note that U. D. 1 is classed as being "more resistant than H 109."

It may interest you to know that we have found U. D. 1 to be extremely susceptible to eye spot on this plantation.

On January 25 of this year we wrote you regarding an outbreak of eye spot in one of our variety plots, at an elevation of 700 feet. U. D. 1 appeared to be the main source of infection in this case, and was affected to a much greater degree than any of the other varieties, quite a number of stools being killed off by the disease. The cane was mature at the time of the outbreak.

It is interesting to note that Paia F which was in direct contact with the U. D. 1 variety, was affected to a much less degree. We note that Paia F has an eye spot index of over 1000 as compared with 250-500 in the case of U. D. 1.

In August, 1927, we established a variety area in a field of D 1135, at an elevation of 2,100 feet. The varieties planted are as follows: U. D. 1, P. O. J. 979, P. O. J. 234, K 107, U. D. 5, Honokaa 1, U. D. 50 and K 202.

In February, 1928, eye spot was noted in the U. D. 1 and Honokaa 1 varieties. The attack was very slight at this date, and there was hope that the varieties would recover with the warmer weather. Instead of throwing off the disease, however, the outbreak has gradually increased, and at the present time a large part of the U. D. 1 variety has died.

As the outbreak is so severe, and the disease still spreading, we are left with no alternative, but to plow out the whole plot of U. D. 1 (about 3 acres).

Honokaa 1 is not so badly affected, but we shall plow this out also, and replant both areas with P. O. J. canes.

All the other varieties appear to be fairly resistant to eye spot. U. D. 5 has been affected, but to a slight degree. P. O. J. 213 is worthy of special mention, as this variety has escaped without a leaf blemish, although it is in direct contact with the U. D. 1 plot.

It is also of interest to note that we have a small plot of H 109 in another field at 1900 feet elevation, with almost the same climatic and soil conditions. A small

outbreak of eye spot was found in this variety in February, but the attack was slight, and the cane has now completely recovered.

U. D. 1 seems to be doing fairly well on other plantations, and we thought you would be interested to know that it is a complete failure here due to its susceptibility to eye spot.

Coptotermes Formosanus Shiraki in Bags of Sugar

The photograph (Fig. 1) shows the work of *Coptotermes formosanus*, the Hawaiian soil-nesting termite that was taken from one of five bags of sugar found infested with this insect on Pier 6, Honolulu. Fig. 2 shows sugar bags, from one of which this specimen was taken.

On August 23, we were notified that Captain Rasmussen, of the Matson Navigation Company, while loading sugar at Pier 6 aboard the S. S. "Lurline" located one bag, labeled "Nalo" sugar, infested with termites. Later, four more termite-ridden bags were found and all were placed in the pier office for inspection. We found no trace of the termite at the mill of the Waimanalo Sugar Company, whence the sugar had come, but a brief examination of the area on Pier 6, where the sugar had been piled up for about two weeks, showed *Coptotermes* present in small accumulations of soil on the floor near the gutter pipes, that furnished a certain amount of moisture, and in the woodwork there. Living termites were thus found on the waikiki side of the pier at a distance of at least 200 feet from the entrance to the pier, and abandoned work of these insects was

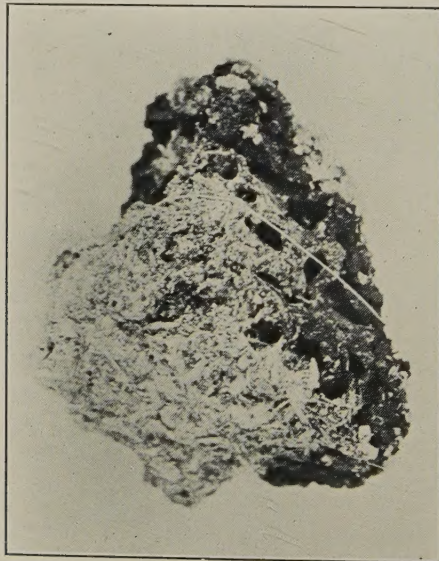


Fig. 1. Work of *Coptotermes formosanus*. Portion of earthy nest found in sugar bag. About natural size. (Photo by D. M. Weller.)

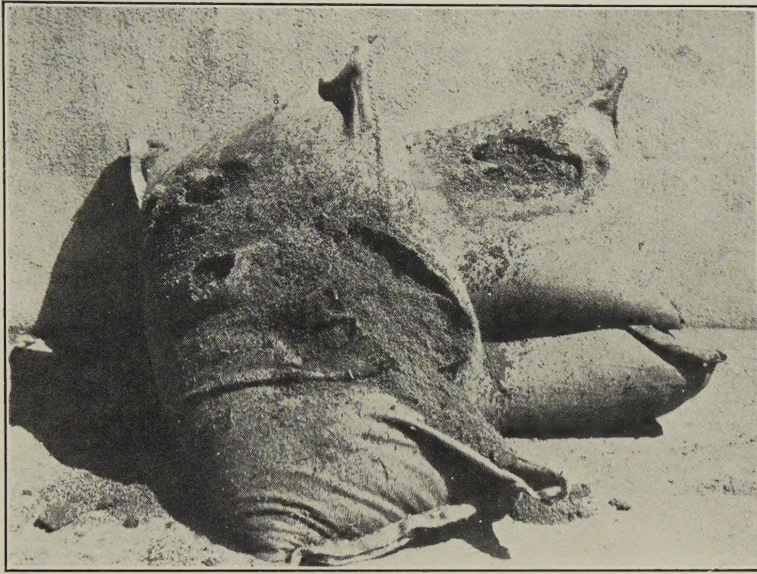


Fig. 2. Bags of sugar attacked by *Coptotermes formosanus*. (Re-produced through courtesy of E. M. Ehrhorn.)

apparent fully 100 feet beyond this, where conditions were drier. *Phidole megacephala* Fab., the common ant enemy of termites, was present in or about termite work. The termites eagerly availed themselves of the moisture of the sugar, biting through the bags where they were in contact with the floor and in several cases they accumulated in the bags themselves a considerable lump of soil as an extension of their nest, both soldiers and workers being found in abundance in the labyrinth of galleries in these moist soil lumps.

The remedy, of course, lies in the destruction of the termite colonies in and about the pier.

F. X. W.

R. H. V. Z.

The Control of Eye Spot Disease by Two-Year Cropping

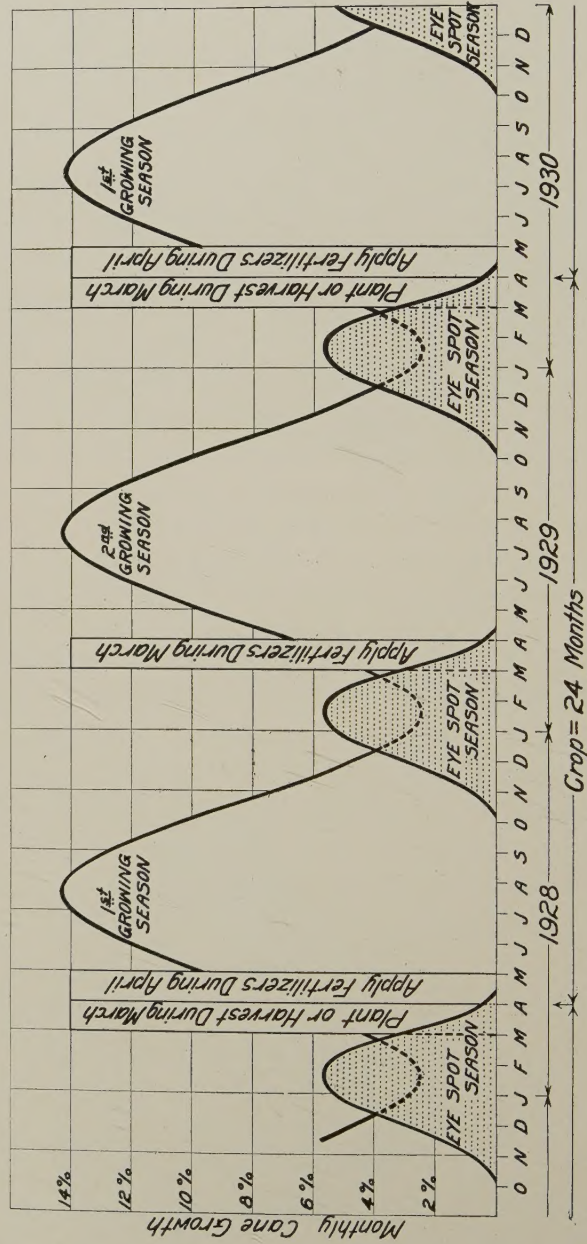
By J. P. MARTIN

In the July *Record*, 1928, an article appeared on "Monthly Plantings of H 109 Cane in Relation to Eye Spot," by the writer. In this article the experimental results pointed out that the older H 109 cane is as it enters the eye spot season the more resistance the cane has to the disease. Numerous observations have confirmed these results wherein late planted or harvested cane in eye spot localities has always been more severely affected than early planted or harvested cane.

Eye spot generally appears in the same locality year after year because the environmental conditions are favorable for the development of the fungus in these

THE CONTROL OF EYE SPOT DISEASE BY TWO YEAR CROPPING

(For Fields Subject to Eye Spot Only)



particular areas. In studying the fields subject to this disease on any plantation, it is quite possible to segregate all fields into two classes, namely, those fields subject to eye spot and those fields not subject to eye spot.

The acreage subject to eye spot will be very small in most cases, as compared to the acreage harvested each year.

As soon as commercially possible, all the eye spot fields are to be brought into a two-year cropping system so that all harvesting or planting of susceptible canes in these fields will take place during March and April of every other year. The chart accompanying this article indicates that planting or harvesting be done during March of 1928, which is just at the end of the 1927-1928 eye spot season. It is also suggested that fertilizers be applied during April of 1928, which is well in advance of the growing season. The maximum cane growth is expected in July.

The object of applying fertilizers early the first season is to take full advantage of the growing period, and also to have practically all the nitrogen utilized by the cane plant by October, 1928, which is just the beginning of the 1928-1929 eye spot season. As illustrated on the chart, the peak of the eye spot season occurs during January and February, or when the smallest amount of cane growth is expected.

The severity of most plant diseases is greatest following rapid succulent growth of the plant. The plant tissues at this stage are very soft, and it is much easier for any parasitic organism to penetrate softer than harder tissue. The eye spot disease is no exception; therefore, it is very essential to slow up or retard the growth of the young cane plant during the winter months. This slowing up process may best be accomplished by avoiding heavy, late applications of nitrogenous fertilizers. Increasing the interval between irrigations also tends to retard the growth slightly.

The second season's application of fertilizer is to be applied during March, 1929, if weather conditions are favorable. Here again the cane has another full growing season, and the seriousness of eye spot on second year cane is more or less negligible when compared to that of young cane.

The crop that was started in March, 1928, will be harvested March, 1930, or 24 months later. This crop has been exposed to two eye spot seasons, but still it has been given the benefit of two full growing seasons.

With such a two-year cropping system it is possible to avoid having young cane entering the eye spot season. If such a method of handling only the very worst affected eye spot fields be adopted, the early sources of infection would be greatly minimized, thus offering greater protection to the surrounding fields.

Concentrating on the elimination of the foci of infection by the adoption of definite agricultural practices as outlined above, or planting such areas with highly resistant varieties, are the most economical control measures of the disease that we have to offer at the present writing.

The ultimate control of eye spot will be effected when a resistant variety that equals or excels H 109 in sugar production is found and can be planted on the affected areas. Many tests are now under way in order to find such a variety, but until this variety is found it will be necessary to resort to the control measures we now have.

At the Waialua Agricultural Company, Limited, approximately 300 acres of H 109 that are subject to severe eye spot attacks are now under the two-year cropping system outlined in this article.

Temperatures Favorable to Zoospore Development in *Pythium Aphanidermatum*

BY C. W. CARPENTER

In December, 1927, the observation was made that a low temperature favors the development of the zoospores of *Pythium aphanidermatum*. At a temperature of about 16° C (60.8° F.) a root preparation was maintained for several days in a continuous stage of sporangia formation and liberation of zoospores. During this period, whenever the preparation was taken from the cool chamber, zoospores were actively swimming, and streaming from the prosperangia was evident. Since it takes approximately 20 to 40 minutes for zoospore liberation after the streaming of the contents of the prosperangium ceases, it is evident that these zoospores, noted immediately on removal of the preparation from the cool chamber, were developed therein. Previously the mode of formation of asexual swimming spores was recorded,* but at that time the factors necessary for their development were not appreciated. In general, they appeared to develop more readily in tap water than in distilled water, which appears now to have been due merely to the few degrees difference in temperature.

After the preparations, in which zoospore formation was active, were kept on the microscope at room temperature for a half hour or longer, the streaming of sporangia gradually ceased. When the preparation was again incubated in the cool chamber, the action was resumed with vigor.

This is an observation in which the life history of *Pythium* correlates with the history of the disease, in that cool weather favors the fungus. The disease was often said to be most noticeable in the winter months, i.e., the cool, wet weather of the year, when the growth appeared to be suddenly checked, followed in drier weather by the drying up and death of the plants. It would appear that with sufficient moisture in the soil and a subnormal temperature, the fungus, by aid of the zoospores, could spread very rapidly through a susceptible root system and thence to other root systems, and to great distances, through the watercourses and ditches. With ordinary soil moisture and temperature, the fungus in the vegetative stage, which reaches its most rapid development at warmer temperatures than the zoospore stage, could spread moderately, since it can grow several centimeters a day.

* Bulletin of the Experiment Station, H. S. P. A., Botanical Ser., Vol. III, Part 1, p. 61.

Recent Developments in the Use of Concentrated Fertilizers

BY GUY R. STEWART

For many years, in the sugar industry of Hawaii, it has been the general practice to make the first season fertilizer applications to the cane crop with high grade concentrated fertilizers. These mixtures have been made up largely from nitrate of soda, potash nitrate, ammonium sulphate, superphosphate, bone meal, potassium chloride and potassium sulphate, and have contained only small amounts of inert material or filler. The amounts of plant nutrients supplied per hundred pounds of fertilizer have ranged from 10 to 12 per cent nitrogen, 3.5 to 9 per cent of phosphoric acid, and from 5 to 10 per cent of potash. Considered in comparison to many of the fertilizer formulas marketed upon the mainland of the United States, the mixtures used in the Islands would all be classed as highly concentrated. Their general employment has resulted in great savings, both in freight and in the cost of applying fertilizer.

Recent developments in the manufacture of unusually concentrated raw materials now make it possible to produce mixed fertilizers which will contain even higher percentages of plant nutrients than have been present in each hundred pounds of fertilizer made up from the old raw materials. The beginning of this manufacture of the newer concentrates can be traced back to the utilization of the war-time capacity for the fixation of nitrogen. This has been one of the great after developments of the manufacture of munitions upon the continent of Europe. Previous to the World War, calcium nitrate, ammonium nitrate, sodium nitrite and sodium nitrate had been made in moderate amounts in Norway by the fixation of atmospheric nitrogen. Calcium cyanamid has been made at Niagara Falls, Canada, since 1909. The production at Niagara, however, though steadily increasing, has not been one of the larger factors in supplying the American market with fixed nitrogen compounds. In the United States, up to the present time, our principal sources of nitrogen have been Chilean nitrate of soda, and latterly, ammonium sulphate derived from by-product cake ovens.

A current review of nitrate production for the past year, made by Dr. L. Bueb, of the German Nitrate Syndicate (2), placed the production of all forms of nitrogen at 1,650,000 metric tons. Each metric ton is equivalent to 1.102 short tons of 2,000 lbs. each. Of the total nitrogen stated above approximately 50 per cent was Chilean nitrate and 40 per cent was fixed nitrogen manufactured in Germany. The other 10 per cent of fixed nitrogen covers the production in France, Italy, Norway and North America. When we consider that prior to the World War the production of Chilean nitrate was estimated to cover more than 95 per cent of the world's supply of combined nitrogen, it is easy to see the tremendous increase in the fixed nitrogen industry which has come about as a by-product of the war time activity in munitions.

Previous to 1914 the fixed nitrogen products most commonly manufactured were calcium cyanamid, with a nitrogen content ranging from 16 to 18.5 per cent, and calcium nitrate, containing approximately 13 per cent of nitrogen. Immediately after the World War, ammonium nitrate was imported from Europe to the United States with a nitrogen content of 34.5 to 35 per cent. More recently a new series of synthetic nitrogen products have been manufactured in Germany. Prominent among these new materials are leuna saltpeter which consists essentially of a mixture of equal parts of ammonium sulphate and ammonium nitrate crystallized together to form a homogeneous salt. Calcium nitrate is also being made with a higher content of nitrogen averaging about 15.5 per cent of nitrogen. It is also claimed that this nitrate of lime is notably less hygroscopic than the older forms of lime nitrate. Trial shipments received here in Hawaii have, however, taken up appreciable quantities of moisture if exposed to the air for any length of time.

Urea is now being made in appreciable amounts from synthetic nitrogen salts. This material is highly concentrated, as it contains 46 per cent nitrogen. Cal-urea is a mixture of equal parts of calcium nitrate and urea. Trial shipments of cal-urea received here have contained 34.3 per cent total nitrogen, of which 6.5 per cent was nitrate nitrogen, 0.5 per cent ammonia nitrogen, and 27.3 per cent was amid nitrogen. There was also 12.77 per cent of lime furnished by the lime nitrate contained in the material.

It is also possible to combine these various synthetic nitrogen salts with phosphoric acid, as in "ammo-phos," and then add a potash salt to the mixture. A series of such mixtures is being manufactured in Germany. One trial shipment has been received in the Hawaiian Islands consisting of "Nitrophoska 1 G." This material was a granular product which did not absorb moisture to any extent when exposed to the air. It contained 16.5 per cent total nitrogen, of which 11.3 per cent was ammonia nitrogen and 5.29 per cent was nitric nitrogen. There was also 16.5 per cent of phosphoric acid and 20 per cent of potash in the mixture. Several other formulas of "Nitrophoska" are being sold in Europe and the Eastern United States.

In considering the value of any of these newer forms of fertilizers there are several points which enter into the solution of such a problem. First among these may be mentioned the effect of the fertilizer or its decomposition products upon the plant and its secondary action upon the soil. There is, then, the question of the compatibility of the material with other possible fertilizer ingredients, both in regard to chemical interaction, which may involve the loss of volatile nitrogen, and the formation of toxic products. There is finally the matter of the value of the small amounts of impurities present in the materials which have been formerly used. A study of the nature and amount of these impurities in the older fertilizer ingredients was reported by Hansson, in the *July Record* (9). A similar investigation upon the newer forms of material now available is being carried out by Van Brocklin and will be presented in the next issue of the *Planters' Record*.

It may be of interest to discuss some of the more important investigations which have been carried out with the various synthetic fertilizers. The major

portion of these studies has been conducted in the Eastern United States or in Europe, but they give a good indication of the value of the materials used upon average agricultural crops, and of the secondary effect of the fertilizer upon the soil.

CALCIUM CYANAMID

A comprehensive series of experiments have been carried on with calcium cyanamid and other synthetic forms of nitrogen at the New Jersey Station(13). It was concluded that the synthetic nitrogen, including calcium cyanamid, gave as good average returns as the sodium nitrate and ammonium sulphate.

Allison and his co-workers(1) in Alabama, have reported an extensive series of field experiments with atmospheric nitrogen compounds. They concluded:

Calcium cyanamid usually was not as satisfactory as the other sources of nitrogen, chiefly because so many factors influence the rate and manner in which the material is decomposed either in fertilizer mixtures or in the soil. When mixed with acid phosphate in large proportions the results were poor, probably owing to the transformation of a portion of the cyanamid nitrogen to dicyanodiamid, a compound which is not only unavailable but toxic for some crops and for the nitrifying bacteria. Where applied separately with acid phosphate the results were good, even with 1000 pounds of an 8-8-4 fertilizer. Calcined phosphate and basic slag appear to be entirely satisfactory as to compatibility as sources of phosphorus for use with cyanamid.

The behavior of cyanamid in the soil depends upon a number of factors, such as time and method of application, and the type, composition, temperature, and moisture content of the soil. Application should be made at the time of seeding, or, preferably, earlier. It is therefore believed that thorough mixing of the cyanamid with the soil is preferable to drilling in the row. Even under the best conditions cyanamid nitrogen is converted to nitrates rather slowly, and for this reason is usually slow to act. The soil conditions which are known to hasten nitrification are, in general, the ones which favor an efficient utilization of cyanamid.

It has been noted in the fertilizer trade journals that when calcium cyanamid is used in mixed fertilizers in moderate quantities it serves as a conditioner, keeping the mixture loose and friable. Under the best conditions a considerable part of the nitrogen of calcium cyanamid is converted into urea, the chief effective nitrogenous constituent of liquid manure. The nitrogen of calcium cyanamid is classed as "organic" by the Association of Official Agricultural Chemists.

AMMONIUM PHOSPHATE OR "AMMO-PHOS"

Owing to the difficulties previously mentioned, which may at times attend the use of calcium cyanamid, a considerable portion of the nitrogen combined in this form at Niagara Falls, is later converted over into two forms of ammonium phosphate. One formula of ammonium phosphate contains 16.45 per cent nitrogen and 20 per cent phosphoric acid. The second furnishes 10.7 per cent nitrogen and 48 per cent phosphoric acid.

A number of experiments with ammonium phosphate have been made both in Europe and in the United States. Allison and his co-workers(1) concluded that ammonium phosphate and ammoniated superphosphate gave an excellent early

growth with both cotton and corn. Both crops when fertilized with these materials were as large or larger than those obtained with any treatments during the first six weeks of growth. The nitrogen of the two materials was as available as that in ammonium sulphate and showed no bad effects except in case of extreme drought, where large applications of all soluble salts injured the plants. Both substances were considered to be good nitrogen carriers.

The growth during the latter half of the season in Allison's experiments, continued to be good, but owing to the abnormally large quantities of phosphate supplied to both the checks and the ammonium phosphate treated plots, the differences became less pronounced as the season advanced. The soil used in these experiments was one which tended to give a notable response to phosphates, so the final result largely obliterated the effect of the added nitrogen derived from the ammonium phosphate.

Coe(5) carried out an extensive investigation at the New Jersey Station in which he used "ammo-phos" as one of the sources of nitrogen and phosphoric acid. The crops used included potatoes, corn, cotton, buckwheat, and soy beans. He made numerous trials to try to determine the best method of applying his fertilizer mixtures so as to have the nutrients in the zone of early root development and still avoid temporary injury to the plant. His general conclusions were that the ammonia of the "ammo-phos" furnished a supply of nitrogen which was readily available for the plant's use. The phosphate content appeared to be equally as valuable as that derived from other phosphate sources.

CALCIUM NITRATE

Shipments of Norwegian nitrate of lime were made for a number of years to Hawaii. Some plantations are still continuing to use lime nitrate, but considerable difficulty was experienced in handling this fertilizer during periods of wet weather owing to the rapidity with which it absorbed moisture. The lime content of this nitrate was also found to be extremely irritating to small cuts upon the laborers' hands.

Experiments carried out at Waipio substation, as well as upon several of the plantations, showed that nitrate of lime was equal to nitrate of soda as a fertilizer for cane. This agrees with the results obtained in numerous experiments which have been conducted in Europe with a variety of crops.

The new lime nitrate now imported from Germany is a white crystalline product. Approximately 4 per cent of ammonium nitrate has been added to this new material to aid in crystallization and to increase the nitrogen content. We have previously referred to the fact that this new nitrate of lime readily takes up moisture if exposed to the air.

AMMONIUM NITRATE AND LEUNA SALTPETER

During the period that ammonium nitrate was being imported into Hawaii, the writer gave a resumé in the *Planters' Record*(14) of experiments in which it had been used. These experiments indicated that ammonium nitrate was a valuable fertilizer which gave results comparable to those obtained with either nitrate of

soda or ammonium sulphate. This conclusion was confirmed by the results of field experiments at Waipio substation, where the same yield of cane was obtained with equal amounts of nitrogen derived from ammonium nitrate and nitrate of soda.

Ammonium nitrate has given considerable difficulty in humid climates through its tendency to absorb moisture and later solidify in a solid cake. In order to overcome this trouble, and also to avoid the import duty levied on ammonium nitrate, this salt has been combined with an equal amount of ammonium sulphate while the two salts were still in solution. The product after crystallization is a combination of the two compounds, and is only moderately hygroscopic. The trade name of this combined salt is "Leuna Saltpeter." A few trial shipments have been received in Hawaii. This fertilizer has a nitrogen content of 26 per cent, of which 19 per cent is ammonia nitrogen and 7 per cent nitrate nitrogen.

Kuyper(11) has carried out several series of field trials with leuna saltpeter upon sugar cane in Java. The nitrogen derived from this source was compared with the nitrogen of ammonium sulphate. Equally good yields were obtained with both nitrogen salts. Graftiau and Hardy(8) used leuna saltpeter upon field crops in France. The return was as good as with nitrate of soda and sulphate of ammonia.

UREA AND CAL-UREA

The most concentrated nitrogenous fertilizer so far developed is urea, which, as we have mentioned previously, contains 46 per cent of nitrogen. Although it is a comparatively new material to be produced on a large commercial scale, a sufficient amount has been manufactured in the past so that a large number of experiments have been conducted with it in various European countries and in Java.

In general the crop yields obtained with urea have been favorable to this material, though there were some conflicting reports as to its value. Von Knieriem(10) in Germany, found that urea gave better results with stock beets and potatoes than he obtained with leuna saltpeter or ammonium sulphate. Chevalier(4), in France, carried out a series of pot experiments with spring wheat in which urea gave yields equal to those obtained with nitrate of soda.

Truffant and Bezssonov(15) experimented for four years with urea and a series of mixtures of nitrogenous salts consisting of ammonium sulphate, sodium nitrate, ammonium nitrate and cyanamid. The crop used consisted of mustard, barley, beets and potatoes. The best yields were obtained when urea was combined with one or more of the other forms of nitrogen. The results for these partial urea mixtures excelled those obtained with urea alone.

Kuyper(12) and van Harreveld-Lako(16) both carried out field trials and laboratory tests with urea as a fertilizer for sugar cane in Java. They both reported that urea was too hygroscopic for Javanese conditions. Kuyper carried out a series of leaching trials with urea in soil columns. He concluded that the probability of loss by leaching was too great to justify the extensive use of this material in Java.

Brioux(3) studied the changes in soil reaction of several French soils when additions of urea, ammonium sulphate and nitrate of soda were used. Up to two days, urea caused an increase in alkalinity, due to the formation of ammonium carbonate. After this time nitrification proceeded rapidly and the soil was finally more acid than was originally the case. With ammonium sulphate on these same soils there was, in a few cases, at first a slight increase in alkalinity. This was followed in all soils by a steady change of reaction towards the acid side. With nitrate of soda there was first an increase of alkalinity and then a decrease, though the final reaction of the soil was slightly more alkaline than it had been previously.

Couterrier and Perraud(6), likewise working in France, found that urea was converted over to ammonium compounds and nitrates with great rapidity in average soils. Craig(7) made this same observation in his experiments in Mauritius, and reported that urea compared favorably with nitrate of soda and ammonium sulphate in availability. He noted, however, that urea was extremely hygroscopic under Mauritius conditions and could not be mixed with soluble superphosphates.

No extended investigations have been reported with "cal-urea," but there is every reason to believe that the results obtained with it upon crop growth will be similar to those reported for urea alone.

NITROPHOSKA

These materials, as previously mentioned, contain high percentages of nitrogen, phosphoric acid and potash. The formula No. 1 G, a shipment of which has been received here in Hawaii, is not appreciably hygroscopic. In the Eastern United States, nitrophoska No. 3 has been offered for sale. This material contains 15.6 per cent nitrogen, 32 per cent phosphoric acid and 16 per cent potash. It is probable that these materials will be used as the basis of high analysis concentrated mixed fertilizer by the addition of nitrogen, phosphates or potash salts to suit the needs of special districts.

DOUBLE AND TREBLE SUPERPHOSPHATE

These materials are an excellent source of concentrated available phosphates. Irrespective of whether they are called double or treble superphosphates, the amount of phosphate present ranges from 45 to 52 per cent of phosphoric acid. These high grade superphosphates promise to be a great convenience to the fertilizer manufacturer in making up formulas with a large content of available phosphate.

In conclusion, it may be stated that the survey of the literature which the foregoing discussion summarizes briefly, indicates that the new concentrated sources of nitrogen and phosphoric acid give every promise of being fully as valuable for agricultural crops as the materials previously employed. In addition, there is a notable saving possible in freight and handling charges in applying less bulky fertilizers.

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Notes on the Rice-Borer, *Chilo Simplex*

BY R. H. VAN ZWALUWENBURG, E. W. RUST AND J. S. ROSA

The recent introduction into Oahu of the rice-borer, a pyralid moth known as *Chilo simplex* (Butl.), confronts the Hawaiian rice industry with a pest of major importance, which, unless brought under control, threatens to seriously cripple rice growing in this Territory. As far as is known this insect is not a pest of sugar cane.

As soon as the importance of the rice-borer was realized, the Territorial Board of Agriculture and Forestry and the Experiment Station of the Hawaiian Sugar Planters' Association undertook as a cooperative project the introduction of rice-borer enemies from the Orient. D. T. Fullaway, of the Board of Agriculture and Forestry, and F. C. Hadden, of this Station, left for Japan in March to obtain parasites, which have been handled in Honolulu by the writers.

ORIGIN AND INTRODUCTION

The presence of a moth larva new to these Islands, working within the stems of rice, was first called to the attention of Mr. Fullaway on March 1 of this year, by K. A. Ching, of the Pacific Guano and Fertilizer Company. The rice growers at Honouliuli, from whom the original complaint came, stated that they had first noticed the work of the insect in the fall of 1927. A rice-straw buyer in close touch with the industry, claims to have noted borer work in straw for the past five years.

Oahu is the only island of this group at present known to be infested by the rice-borer.* All rice lands of the island show greater or less infestation at the time of writing. A territorial quarantine now in effect against the movement of rice-straw in any form to the outlying islands will, it is hoped, keep the rest of the group free from the pest.

It is reasonably certain that the rice-borer is an immigrant from Japan, where it is a recognized pest. That it gained entrance to the Territory in rice-straw used as packing for merchandise also seems certain, for since its discovery in the fields here it has on several occasions been intercepted by Territorial quarantine officials in such material from Japan, and rice-straw has been used as packing for many years.

Chilo simplex was originally described from Formosa, and is known in Japan as the "two-brooded rice-borer" to distinguish it from an even more serious pest known as the "three-brooded rice-borer" (*Schoenobius incertellus* [Walker]). It is not certain that *Chilo simplex* occurs in India. The moth called *simplex* in India is a pest of rice and of sugar cane, but on comparison of larval descriptions it seems probable that it is not the *simplex* of Formosa, Japan and Oahu. On the other hand, *Chilo oryzae* Fletcher, of India, reported on rice only, corresponds closely with our *simplex*. The numerous members of this genus of moths are in need of careful study, and only a competent examination of type-material can determine the relation of the Indian species to our own.

NATURE AND SEVERITY OF DAMAGE

The typical symptom of *Chilo* attack in rice is the killing of the central leaf. This is caused by the larva feeding within the stem and killing the tender inner leaf-tissues. Badly infested rice shows a high percentage of dead shoots and leaves; is easily flattened by wind and rain, and often, even though the head forms, fails to set grain. The loss has become so severe in some sections that at least one small grower has abandoned the planting of rice. A Japanese grower at Heeia states that a field (area not specified) which has hitherto always produced between 30 and 40 bags, will this crop yield not more than 5 or 6 bags. This grower last year noticed the rice-borer in small numbers for the first time. At Honouliuli several small areas were so badly damaged that no attempt was made to harvest the July crop. It is stated (with what accuracy is not certain) that the Hawaiian

* Since the above was written, this insect has been found widespread on the island of Kauai.

variety of rice suffers more than the Japanese variety, which matures in about a month's less time than the former.

The eggs of the rice-borer are disc-shaped, creamy-white when first laid, and are deposited in irregular clusters, either on the leaf-blade or tucked down between the leaf-sheath and the main stem. The eggs, which are overlapped like shingles, often number over 100 in a single cluster. They hatch in from six to seven days. The young larvae make their way down the leaf and enter the stem, where they commence their feeding. When full-grown the larvae are about an inch in length. The pupal stage of about ten days is passed within the stem.

Large numbers of adult *Chilo* moths are caught by light-traps, and trapping gives promise of being a practical means of reducing the rice-borer population.



Fig. 1



Fig. 2



Fig. 4



Fig. 3



Fig. 5

Various stages of *Chilo simplex* and anatomical details of larval structure. The enlargements are not uniform.

- Fig. 1. Adult male moth (wings of left side removed).
- Fig. 2. Pupa.
- Fig. 3. Full-grown larva.
- Fig. 4. Larval spiracle and setae.
- Fig. 5. Abdominal proleg of larva.

HOST PLANTS

The preferred host of the rice-borer is undoubtedly rice. Occasionally barnyard grass (*Echinochloa crusgalli* var. *cruspavonis* [H. B. K.]) and rice grass (*E. stagnina* [Retz.] Beauv.) standing amid growing rice are also attacked, but as a rule plants other than rice usually show little infestation as long as there is standing rice in the vicinity. Once the rice has been cut, however, especially if heavily infested (individual rice stems have often been found to contain upward of ten mature larvae), the rice-borer takes to a number of other plants. It is possible that the borer larva migrates to such hosts from dead stubble or straw, for neither eggs nor young larvae have been found in association with anything but rice.

The most important host of the rice-borer at Honouliuli, in the absence of rice, was the common barnyard grass (*E. crusgalli* var. *cruspavonis*). In July this grass was severely infested, hardly a stem escaping attack, and many of the stools being killed outright. At the same time borers were found to be present in a number of the other grasses, among them: goose grass (*Eleusine indica* [L.]); foxtail grass (*Chaetochloa verticillata* [L.]); and rarely, Panicum grass (*Panicum barbinode* Trin.). Hilo grass (*Paspalum conjugatum* Berg.) has never been found to contain rice-borer larvae, though a few short burrows have been found in it, suggesting that this grass is either too hard for the borer or distasteful to it. Larvae were found to be fairly common in stems of a composite weed (*Eclipta alba* Hassk.) just after the rice was harvested. Recently Q. C. Chock, of the Board of Agriculture and Forestry, found extensive tunnels in the stems of *Phaseolus lathyroides* L. made by a lepidopterous larva believed to be the rice-borer.

NOT A PEST OF SUGAR CANE

No trace of rice-borer has yet been found in sugar cane on Oahu, even when in close proximity to either standing or harvested fields of heavily infested rice. Mr. Hadden writes that in Formosa sugar cane is rarely, if ever, attacked by *Chilo simplex*, and suggests the possibility that previous records of such attack may be attributed to the presence in that country of a closely related and scarcely distinguishable borer. It is well known that certain species of *Chilo* in other countries (notably *Chilo loftini* Dyar in Mexico) seriously attack sugar cane in addition to rice and other grasses. It is conceivable that the rice-borer present here may ultimately transfer its attention to sugar cane, for in the laboratory partially grown larvae placed on seedling varieties grown from cuttings caused the death of the young shoots. There is, however, no cause for immediate alarm as concerns the cane industry; in fact, the situation becomes more and more encouraging as the negative field evidence accumulates.

LOCAL ENEMIES

Several enemies already established here have been noted preying on the rice-borer:

1. *Trichogramma minutum* Riley, an egg-parasite of cosmopolitan distribution, has been reared from *Chilo* eggs collected at Honouliuli.

2. An ichneumonid wasp, *Nesopimpla naranyae* Ashm. occurred in large numbers in rice fields in June and July, and was bred from infested straw. Its parasitism of *Chilo* is not proven, but is probable.

3. *Cremastus hymeniae* Vier., an ichneumonid parasitizing many kinds of lepidopterous larvae, has on two occasions been reared from rice-straw in which its cocoon was found beside the remains of a dead *Chilo* larva. This species has also been noted in rice fields on various occasions.

4. *Polistes hebraeus* (Fab.), a common yellow wasp, was present in numbers in lately cut fields at Honouliuli in June. It was repeatedly observed cutting rice-borer larvae and adults into small pieces, which it rolled into pellets and carried off, presumably to store its nest.

5. Stray larvae of the rice-borer are frequently attacked by the ubiquitous lowland ant, *Phidole megacephala* (Fab.).

6. The mynah bird (*Acridotheres tristis*) undoubtedly accounts for large numbers of *Chilo* larvae and moths, which it picks up in the open fields after the cutting.

FOREIGN ENEMIES

Mr. Fullaway and Mr. Hadden had, up to August, forwarded from Japan ten different lots of insects attacking *Chilo simplex*. These included:

Parasites of the egg:

Phanurus beneficiens (Zehnt.)

Trichogramma japonicum Ashm.

Parasites of the larva:

Undetermined ichneumonid.

Cremastidea chinensis Vier.

Apanteles sp.

Amyosoma chilonis Vier.

Predaceous enemies:

Larvae of an undetermined species of carabid beetle.

The egg-parasites were all reared through a first generation before release in the field. By the middle of August over 33,000 *Trichogramma japonicum* and over 24,000 *Phanurus* had been released in Oahu rice fields. *T. japonicum* has several times been reared from *Chilo* eggs collected in the field, so there is a good likelihood of its establishment here. It is closely related to *T. minutum*, and, like it, is said to attack a wide range of lepidopterous eggs. *Phanurus* is more restricted in its habits, attacking the eggs of only *Chilo* and *Schoenobius*, as far as is known. This last egg-parasite is a native of Java, whence it was introduced into Formosa and later into Japan.

The only others of the above list to be released here were small colonies of *Amyosoma* and of *Apanteles* spp. (including one species parasitic on the cabbage butterfly).

Variation of Soil Depth Within Limited Areas

BY J. P. MARTIN

In an attempt to explain the low yields obtained from Field Mill 5 during the 1928 crop of the Waialua Agricultural Company, Ltd., H. P. Agee, upon visiting the field May, 1928, with Messrs. Verret and Stewart, of this Station, suggested that a few soil borings be made in the field in order to ascertain the soil depth and other possible factors that might have a direct bearing on the low yields.

During the latter part of May, 1928, the writer made a few soil borings, and since there was such a wide variation in depth within a short radius, it was decided to make a series of borings along the level ditches of the field. A total of 32 borings were made and a graphic presentation of the results is best made by the use of small wooden pegs as shown in Fig. 1. In preparing the model for photographing the length of each peg in mm. represented the depth of the soil in inches at that particular location. In Fig. 2 a diagram illustrates the location and depth of soil at each boring.

At the bottom of each boring a hard, thick, coral layer was found which was impervious to water. Field Mill 5 is in a low lying area which heretofore was occupied by the ocean. A possible explanation of the great variation in soil depth may be visualized by observing the irregularities of the ocean floor from a glass-bottom boat, and imagining such a surface covered with soil.

The average depth of soil in Field Mill 5 was comparatively shallow. It was finally agreed that in order to secure greater yields it would be necessary to continue irrigations up to two months previous to harvesting, especially if harvested during the summer months; the application of slightly more fertilizer than the usual practice was also thought to be advisable.

As an outcome of the above investigations the following fertilizer experiment was put in Field Mill 3, which is very similar to Field Mill 5, by R. E. Doty, of the Experiment Station:

	1st Season Nitrogen	2nd Season Nitrogen	Total Nitrogen
6-A Plots.....	50	150	200
6-B "	150	50	200
6-C "	100	100	200

All nitrogen was from nitrate of soda.

Here again the writer made a series of soil borings in each watercourse of the area which was selected for the experiment. Approximately three soil borings were made in each watercourse. The results of the findings are best presented by the graphic presentation as shown in Fig. 3, which was prepared in a like manner to that in Fig. 1. In Fig. 4, a diagram gives the plan of the experiment, the location and depth of each boring made.

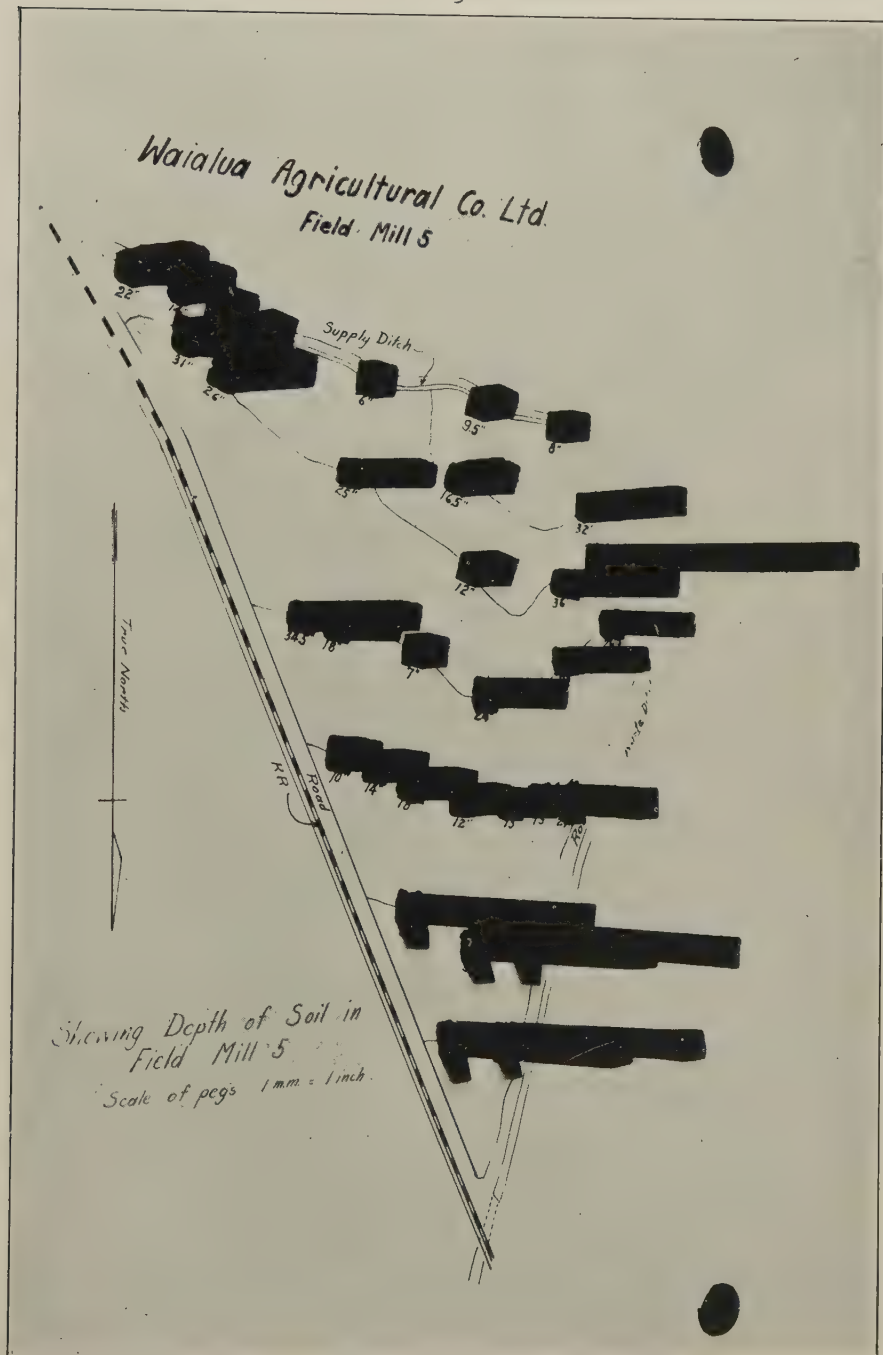
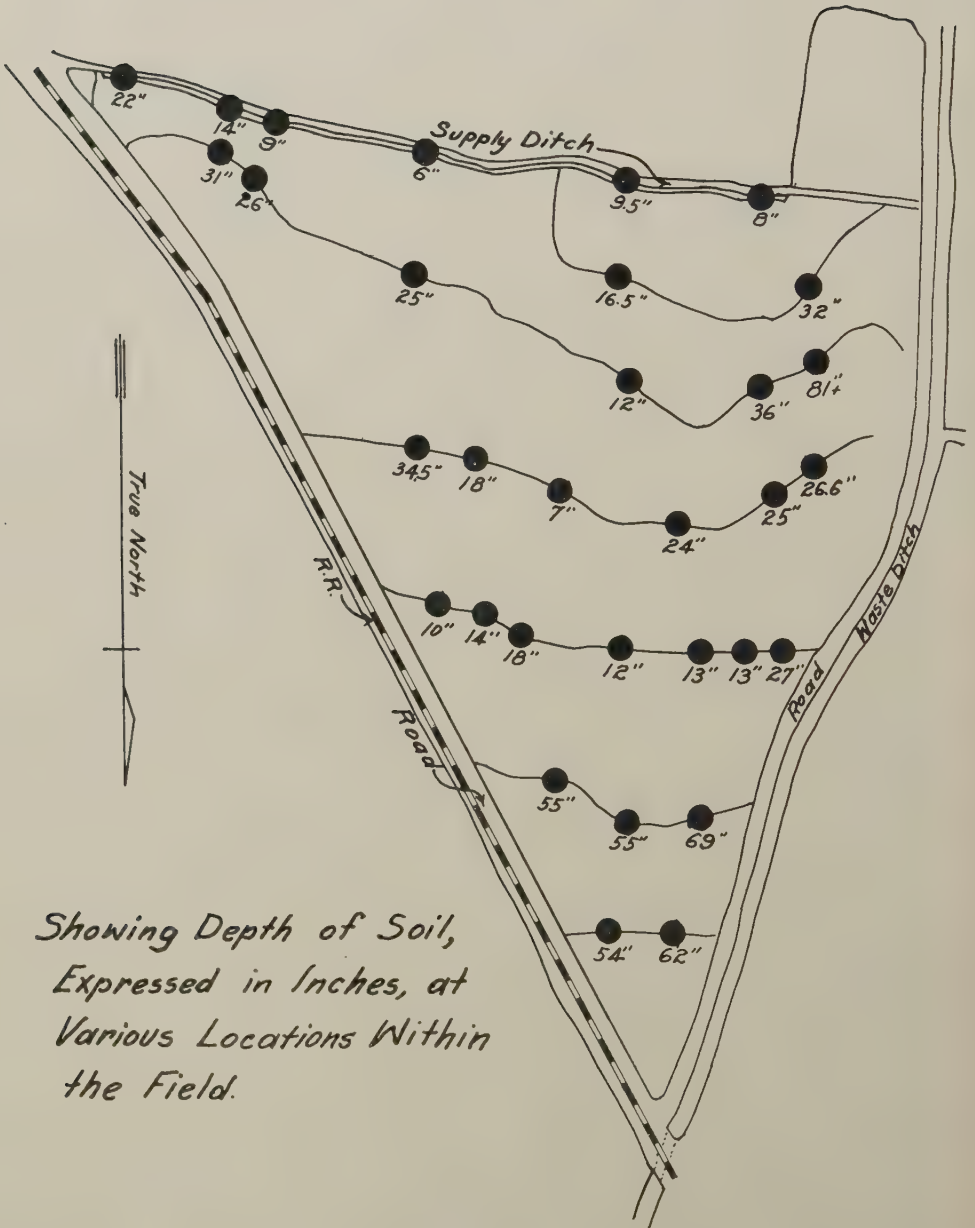


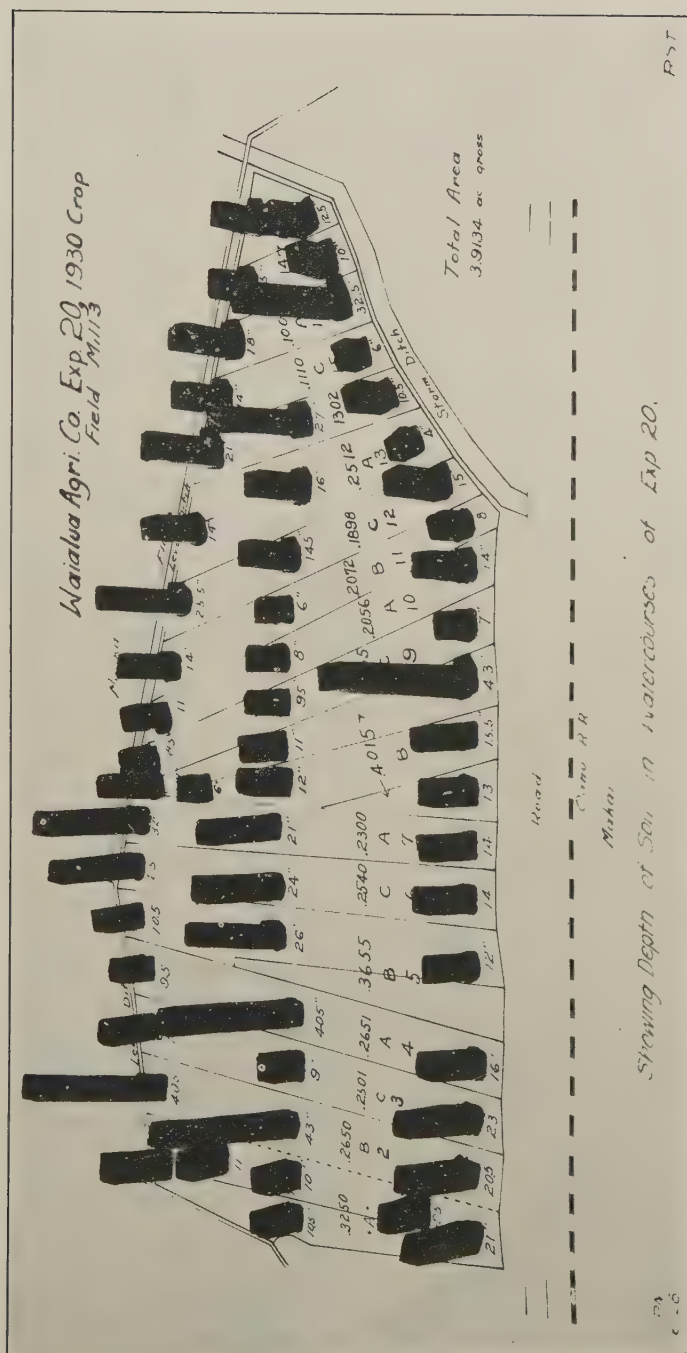
Fig. 1

Field Mill 5, W. A. Co., Ltd.



*Showing Depth of Soil,
Expressed in Inches, at
Various Locations Within
the Field.*

Fig. 2

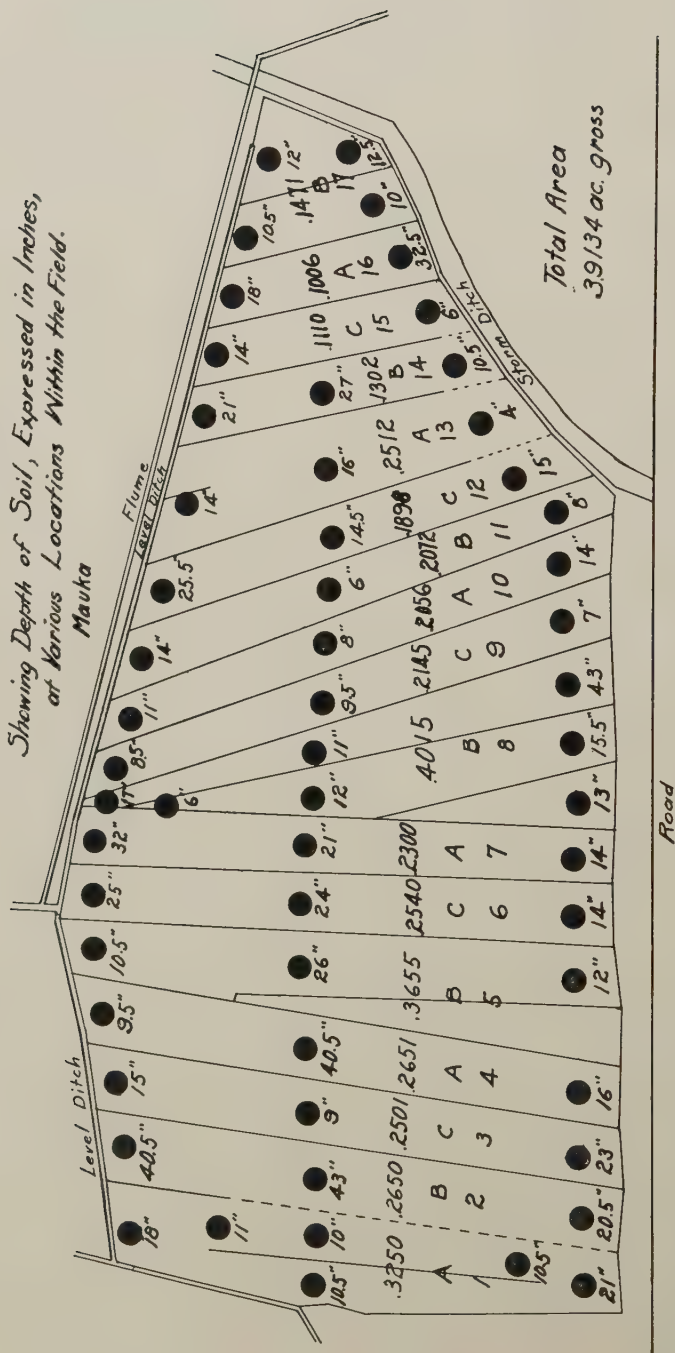


Waialua Agri. Co. Exp. 20, 1930 crop
Field Mill 3.

Field Mill 3.

*Showing Depth of Soil, Expressed in Inches,
at Various Locations Within the Field.*

Mauka



Total Area
3.9/34 ac. gross

Road

Oahu R.R.

Makai

Fig. 4

A hard coral layer was encountered at the bottom of each boring, as was the case in Field Mill 5. In this experiment the depth of soil varied from 4 to 43 inches. The average depth of soil was quite shallow. In order to secure the maximum yields from such fields it seems very essential to keep a good supply of moisture in the soil, even quite close to the harvesting period, so as to prevent the soil from drying out and the cane from dying in the extremely shallow areas.

Often the great variation in results of an experiment might be to a large extent understood if the soil depth was determined. The object of this paper is to show the variation of depth of soil it is possible to have in a limited area, and also to point out that a series of soil borings might aid in explaining the irregular or inconsistent results that often occur in variety or fertilizer experiments.

The Koloa System of Irrigation

BY H. R. SHAW

The Koloa Sugar Company is now changing the layout in all fields formerly irrigated by means of the single line or "Hawaiian furrow" system to a method of irrigation which has been developed on the plantation. This new system of irrigation promises to be most effective in applying an even distribution with the greatest economy of labor and water. The Koloa system is not a radical departure from the present practice, but is the utilization of the best features of several standard methods used for years in the islands, supplemented by an original feature which more than doubles the effectiveness of the Hawaiian furrow system.

The Koloa system, on an average of ten irrigations, has more than tripled the acreage covered daily by each irrigator, with half the application of water used by the common Hawaiian furrow system of irrigation.

Layout: The field is prepared for the so-called two-way system, which is already well known on most plantations. The watercourses are 30 feet wide, and are prepared so that the water is diverted simultaneously from one watercourse to the furrows lying directly opposite each other. A dam is placed down the center of every two watercourses, thus making each line 30 feet long.

An important feature in the layout of the field is that the spillway from watercourse to line is about six inches higher than the bottom of the watercourse. Hence, when the line is filled with water there is no backflow and wastage in the watercourse.

The original feature, and the one which gives the Koloa system its great economic value, is in the use of a portable pani. The pani framework is constructed from three pieces of $\frac{1}{2}$ "x1"x2', formed as a triangle. At the apex of the triangle is a board $\frac{1}{2}$ "x8"x8", with rounded corners, which is placed as a base support. The framework is covered with burlap bagging, such as old fertilizer or

Portable Pani for Koloa System

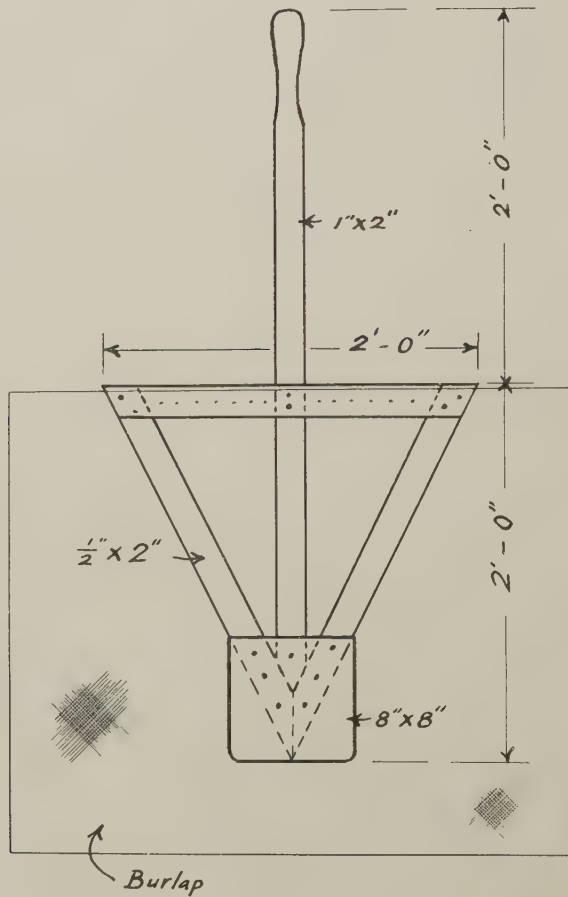


Fig. 1

sugar bags. The bagging is tacked across the broadest side of the triangle, and falls loosely across the framework. A handle of 3" board, tapered at the top, is nailed to the base support and across the framework. These specifications are approximate only and may vary to suit local conditions.

The pani is placed in the watercourse just below the spillway to the first line. The base support is put in the bottom of the watercourse, and the sides of the bag extended over the spillway. The system can handle a large stream of water, which is diverted over the spillway and into the furrow. The line is filled quickly, and the water cannot drain back into the watercourse because of the high spillway.

When the first two lines are filled the irrigator pulls his pani down the watercourse to the next spillway, and the process is continued for the next unit.

Results: Results of ten irrigations in mature cane show that the system is effective under field conditions; and promises a sound, efficient method of handling one of our major irrigation problems.

The following results are in H 109 cane, eight to thirteen months old, on level land. The field was not especially prepared for the Koloa system, but is a ratoon field with the layout of the watercourses changed to fit the new method.

H109, THIRD RATOONS. LEVEL LAND—12.04 ACRES. FIELD 7B. STARTED
MAY, 1927

	Total Water		Ac. In. per Ac.		Gals. per M.D.		Ac. per M.D.	
	One		One		One		One	
	Line	Koloa	Line	Koloa	Line	Koloa	Line	Koloa
Rd. 9.....	1,520,095	953,114	3.301	2.915	124,089	317,705	1.384	4.01
Rd. 10.....	2,013,759	982,441	4.373	3.005	141,316	327,480	1.190	4.013
Rd. 11.....	2,155,504	1,015,026	4.680	3.105	151,263	338,342	1.190	4.013
Rd. 12.....	2,202,753	1,063,903	4.783	3.254	149,339	303,972	1.150	3.440
Rd. 13.....	2,724,114	1,129,074	5.915	3.453	209,547	396,166	1.305	4.225
Rd. 14.....	2,996,200	1,106,264	6.506	3.384	190,235	368,755	1.077	4.013
Rd. 15.....	3,066,258	1,282,224	6.658	3.922	278,751	466,263	1.542	4.378
Rd. 16.....	3,234,071	1,524,983	7.02	4.66	340,428	406,662	1.785	3.211
Rd. 17.....	4,775,795	1,623,738	10.37	4.96	353,762	463,639	1.256	3.440
Rd. 18.....	4,047,069	2,017,018	8.79	6.17	311,313	403,404	1.305	2.408

The following data are available on the first five irrigations in a plant field especially prepared for the Koloa system. Mr. Moir, manager, remarks: "Field 40 has not yet reached the stage where full advantage of the new system may be taken. Rains made more frequent rounds unnecessary, and weeds retarded irrigators. Very shortly now this field will speed up in area irrigated per man day."

PLANT FIELD NO. 40—STARTED FEBRUARY, 1928. SEEDLING AREA. LEVEL
LAND—33.89 ACRES

	Round No. 1	Round No. 2	Round No. 3	Round No. 4	Round No. 5
Total Water.....	3,166,294	2,782,767	2,312,564	3,244,250	3,868,829
Acre Inches per Acre.....	3.47	3.05	2.535	3.525	4.204
Gallons per Man Day.....	52,396	57,914	60,459	66,548	67,874
Acre per Man Day.....	0.556	0.699	0.878	0.695	0.594

Fields 8A and 8B are ratoon fields changed to the new system immediately after harvesting. Water figures are not available, but the following data on area covered per day show how soon it is possible after starting the field to maintain a large area per man day irrigating in spite of the fact that some weeding had to be done.

ACRES PER MAN DAY

Round Number	Field 8A	Field 8B
1	0.911	0.904
2	0.867	0.904
3	1.367	0.961
4	1.555	1.318
5	1.804	1.464
6	2.405	1.564

There are many obvious advantages to the Koloa system of irrigation:

1. *Economy of Labor:* The striking point in the data available on the Koloa system is the large area covered by each irrigator. Under the furrow system now in general use, one acre per man day is considered a fair average, and in many cases the area covered per day falls far below this figure. The Koloa system, in mature cane, averaged 3.72 acres per man day. This result is possible because of the large stream handled by the irrigator.

2. *Economy of Water:* A more economical application of water is possible with the Koloa system. Under the usual method of furrow irrigation the low flow, resulting in greater percolation loss as well as loss of head in heavy cane, makes an application of from 4 to 10 acre inches per acre necessary. Half this amount is used by the Koloa system.

3. *Even Distribution:* The large flow causes the entire line to be filled quickly and uniformly. There is less percolation loss at the head of the line than there is with the small flow of the furrow system. All of the water admitted to the line is retained, as the high spillway prevents the return of the water to the watercourse.

4. *Elimination of Panis:* The use of the portable pani removes the necessity of using from twenty to fifty opala panis per watercourse, as is now the case with the furrow system. Not only is a considerable item of expense in preparing the panis and consequent delay in irrigation eliminated, but seepage from poorly constructed dams is removed.

5. *Treatment of Plant Fields:* Danger of washing out lines in irrigating plant fields is lessened by use of the Koloa system. The end of the bag pani may be placed on top of the spillway and the water diverted over it into the furrow. In this way the head of the line is not eroded, and the spillway soon becomes firm and compact. It is advisable in early irrigations of plant cane to place the pani so that water is diverted into one line only and then into the other. It is necessary, of course, to use a much smaller stream in irrigating young plant.

6. *Better Supervision:* With the Koloa system it is necessary to push the cane away from the watercourse after a few months' growth. This procedure increases the efficiency of the irrigator, and insures closer and more rapid supervision.

The only apparent drawback to the Koloa method of irrigation is the possibility that, because of the large stream used, the watercourses and lines may be eroded to some extent, especially on pali land.

The objection that it is impossible for the irrigator to weed and strip as he irrigates is a negligible one, as the economy of labor in irrigating more than offsets the extra labor required for separate weeding and stripping operations. It has been definitely proved by innumerable experiments and observation that the efficiency of the irrigator is greatly lessened when he is forced to weed and strip as he works.

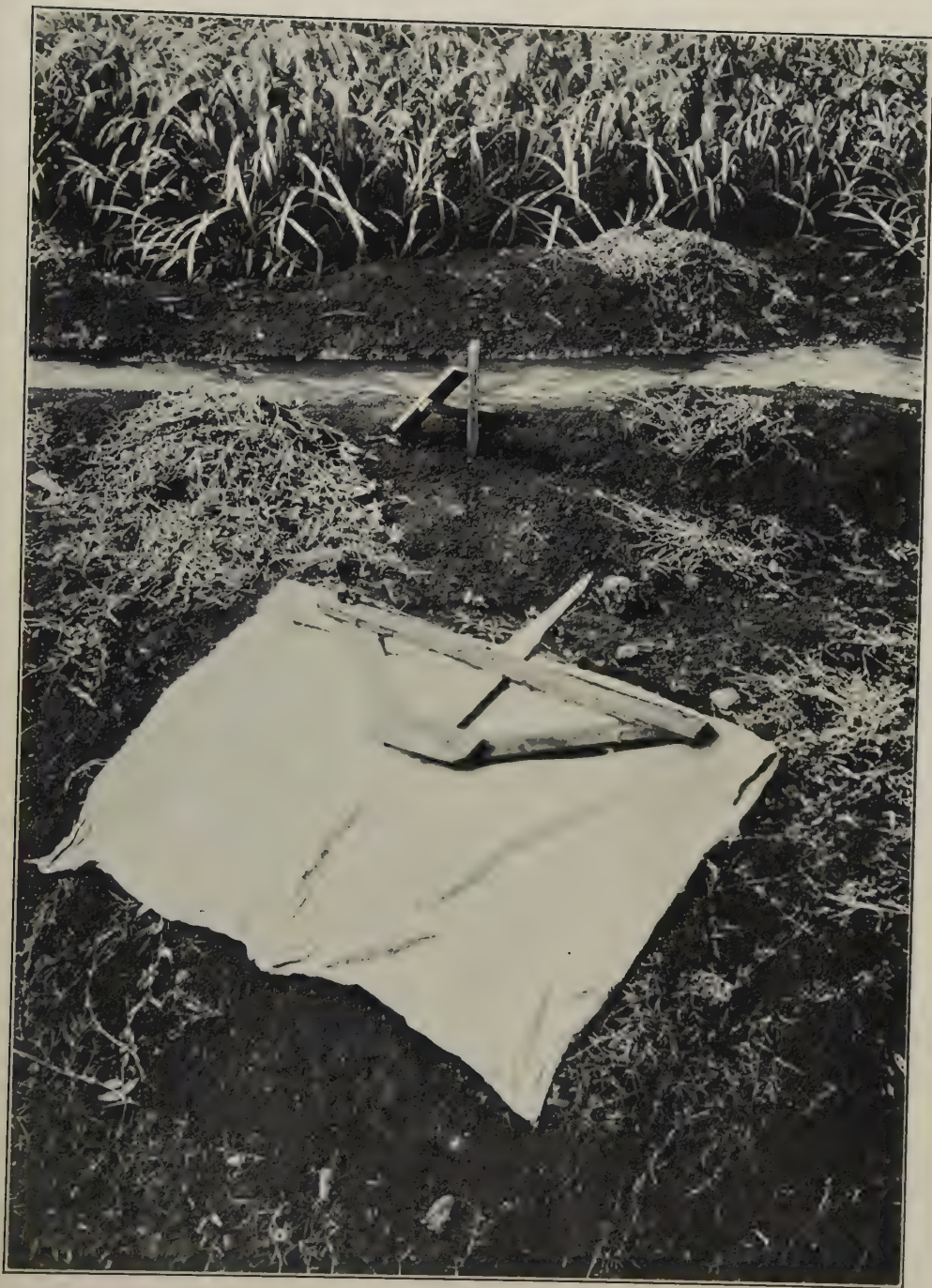


Fig. 2. View of pani framework.



Fig. 3. Upstream view of pani in place.



Fig. 4. Downstream view of pani in place.

Watercourse Layout

Koloa System Of Irrigation

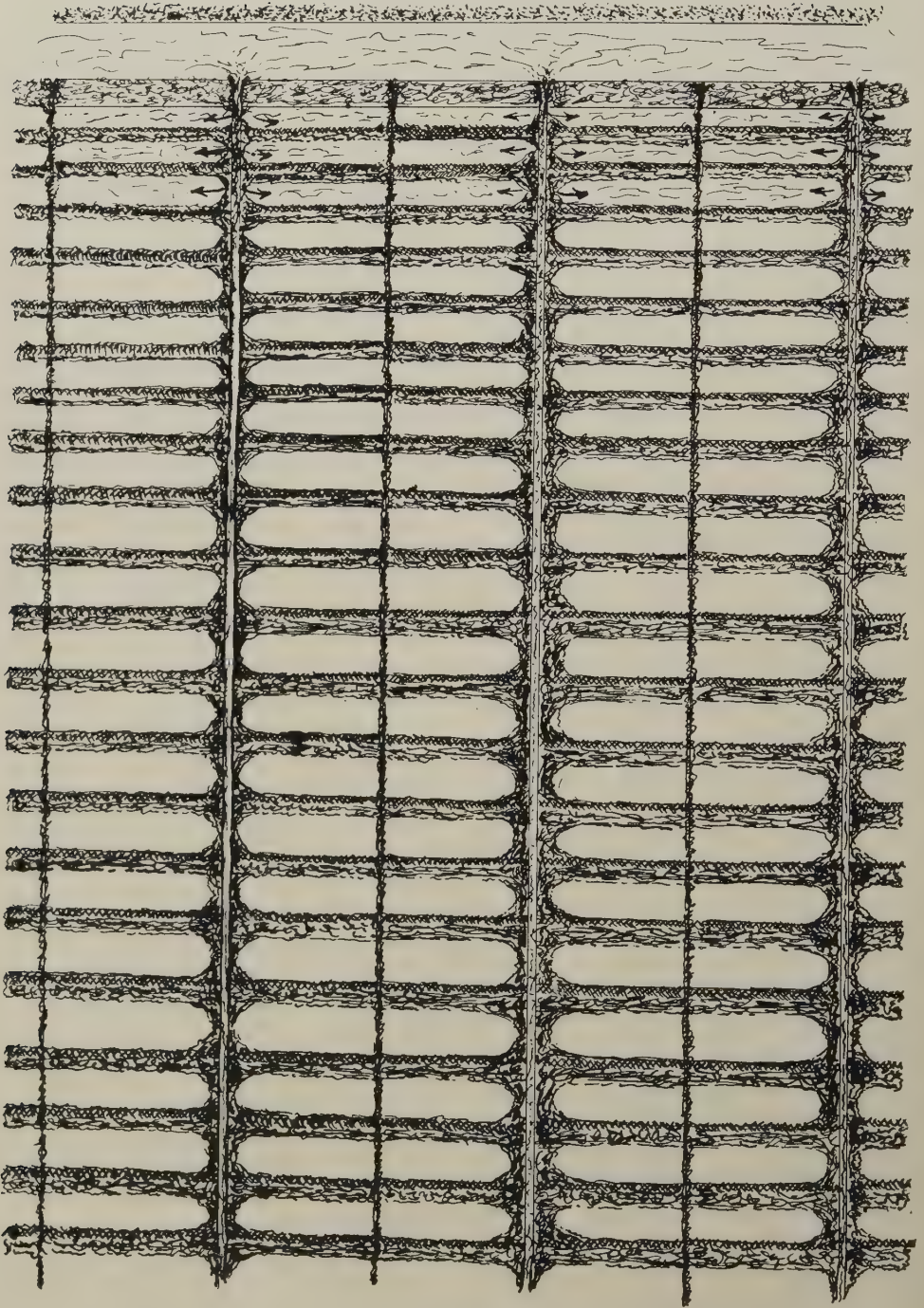


Fig. 5

How Are We to Recognize a Super Cane?

By J. A. VERRET AND A. J. MANGELSDORF

To produce seedlings is no longer difficult. Methods of making crosses and germinating the seed have been developed to a point where seedlings of a desired combination can be obtained in large numbers at low cost, if both parents are reasonably fertile.

The outstanding difficulty at the present time is the matter of determining which seedling, of the large number produced each year, is the most profitable one for a given set of conditions.

In the past, much of the selection work throughout the Islands—too much of it, we believe—has been carried on somewhat as follows. When new seedlings are received from the Station, or from other plantations, the seed is planted out, often without check lines of the standard variety with which to compare them. In due course those which look promising are “spread” again, often without check plots of the standard variety. If a given seedling continues to present an attractive appearance it is multiplied further, and in time may come to occupy a considerable acreage, without having been subjected to a single yield test which might have been expected to give reliable figures on cane tonnage or sucrose content; that is to say, in comparison with the standard cane planted at the same time in adjoining plots. Meanwhile, the seedlings not so attractive in appearance have been discarded, again often without a single reliable figure to warrant the action.

Appearance is a sufficiently safe basis on which to discard the conspicuously inferior seedlings. However, when it comes to determining differences of only 10 to 20 per cent, judgment based on mere appearance becomes a matter of guesswork. One can easily satisfy himself on this point by attempting to guess the yields of a number of small plots of one of the standard varieties and then weighing these plots to check up on his guesses. If it is difficult to be sure of a 10 per cent difference in small plots of one and the same variety, how much more difficult is it to determine by observation the relative yields of different varieties with different growth habits and differences in sucrose content. The answer is that it can't be done; at any rate, not by many of us.

Yield figures from a *poorly planned* experiment, however, may be just as misleading as conclusions based on observations. Without check plots to detect soil variation, the highest yielding seedling is too often the one in the most favored spot rather than the inherently superior one.

The only safe procedure, we believe, is to plant the aspirants to the heavy-weight championship in checkerboard plots, comparing their yields with adjacent check plots planted to the present title holder. Neither should this comparison be merely a visual one based on appearance. Except for the obviously inferior ones, actual weights and juice determinations should be recorded. Where a complete

juice analysis of each seedling is not practicable, a very good approximation of quality ratio may be had from a refractometer reading of a small sample expressed by means of a pair of pliers from sections of a number of sticks. This method is described in greater detail in another paper in the present number of the *Record*.

Observation notes are, nevertheless, an important and valuable adjunct to yield figures. Many of the habits and qualities of a seedling may be brought to light only by repeated observation, and notes taken at various stages of growth are extremely useful. They should, however, be used as supplementary to and not as a substitute for actual harvesting figures.

SEEDLING TESTING IN JAVA

The rapid multiplication of the Java supercane P. O. J. 2878 from a single stool in 1922 to over 300,000 acres in the last crop is now a familiar story. Instead of depending on observations over a period of years to discover their superior canes, the Java planters try out their promising seedlings, as soon as seed is available, in trial plots checkerboarded with plots of their standard cane. With reliable yield figures from these sources at hand, they are able to decide promptly whether to discard a given seedling or whether to spread it as rapidly as possible.

The rapidity with which P. O. J. 2878 was spread points to the efficacy of their system of testing.

In 1924, two years from the time that only a single stool of P. O. J. 2878 existed, there were planted in different parts of Java fifteen semi-final and final tests, each with four or more replications and with alternate plots of the standard variety. When these tests were harvested in 1925, it was found that this cane had outyielded its competitor in thirteen of the fifteen trials. During the same year P. O. J. 2878 was included also in thirty-eight preliminary trials and in twenty-nine of these it outyielded its competitor.

The next year (1926) P. O. J. 2878 was tried against their standard canes in 254 semi-final and final trials. In 238 of these it outyielded its competitor.

In 1927 it was included in 847 trials, in 724 of which it occupied first place.

Having at hand the figures from so many experiments, each laid out in such a manner as to give reliable results, the Java planters had good reason to feel that they were safe in spreading the new supercane as rapidly as possible. Had they been relying on mere observation, the adoption of this cane would certainly have proceeded much more slowly, with a loss to Java in the meanwhile of thousands of tons of sugar a year.

Java harvested last year, in addition to large numbers of preliminary trials, 1055 semi-final and final trials. These were all checkerboard tests, each with from four to twelve replications.

Java's crop totals something over 450,000 acres of cane each year. This means a semi-final or final variety test for each 400 acres.

If our seedling testing were on a similar scale, we would be harvesting, with our yearly crop of around 125,000 acres, something like 300 semi-final and final yield trials, whereas up to the present we have averaged scarcely a half dozen

a year. We are speaking, of course, of checkerboard tests with replications, comparable to our fertilizer tests.

When we reach Java's level in seedling testing, a large plantation cutting, say, 6,000 acres of cane a year will be harvesting yearly around fifteen variety tests, each with four or more replications.

PROPOSED SEEDLING TESTING PROGRAM FOR HAWAII

In an effort to reduce in the future the proportion of variety tests which may give misleading or at best indecisive results, the agricultural department issued to its members several months ago a memorandum on plot arrangement in variety testing. This memorandum is reproduced below. Obviously it cannot be final, but must undergo revision as our knowledge of the problem increases.

We submit it, however, as the best procedure we are able to offer at the present time. Any suggestions as to its improvement will be welcomed by the agricultural department.

Plot Arrangement in Variety Testing:

Variety Tests as employed in these Islands may be classified as:

1. Preliminary Trials.
2. Semi-final Trials.
3. Final Trials.

Each of these will be discussed separately.

1. Preliminary Trials

This form is used for Field Trials 2 and 3 of new seedlings and for first trials of seedlings newly introduced from other localities.

Since the number of seedlings to be tested in preliminary trials is usually large and the amount of seed limited, replications are not ordinarily desirable.

The size of the individual plots may vary from 10 to 200 feet of line, depending upon the amount of seed available, and upon the degree of promise of the seedling in question.

It is preferable to have alternate plots planted to the standard variety. However, if the soil is quite uniform, and space is limited, the number of checks may be reduced to one in three without serious loss of accuracy.

Guard rows of crop cane are used to separate the variety test from roads, level ditches and other disturbing factors.

The plots should be as nearly square as possible, in order to reduce to a minimum the competition between varieties which occurs along the borders of the plots.

While the size, shape and arrangement of the plots must necessarily be governed somewhat by such considerations as the contour of the land, the irrigation system, and convenience in planting and harvesting, the principle illustrated in Fig. 1 should be adhered to as closely as practicable.

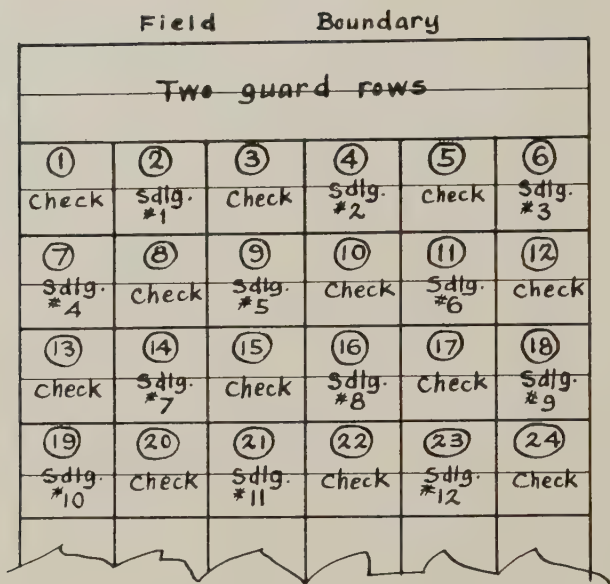


Fig. 1. Model plan for preliminary trial.

Number of plots: One of each seedling, alternating with check plots of the standard variety. If the soil is very uniform, one check plot to two plots of seedlings may be sufficient.

Size of plots: Ten to 200 feet of line.

Shape of plots: Preferably square, in order to reduce to a minimum the effect of competition along plot borders.

Guard rows: Experiment to be separated from roads, level ditches and other disturbing influences by guard rows.

Numbering of plots: Each plot numbered, to facilitate identification.

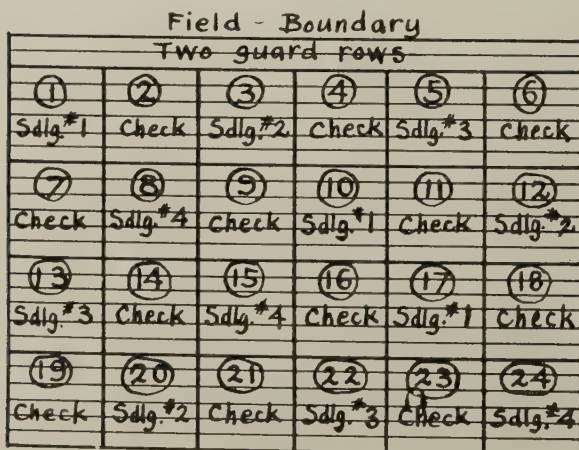


Fig. 2. Model plan for semi-final trial.

Number of plots: From two to four of each seedling, alternating with check plots of the standard variety.

Size of plots: From 1/20th to 1/50th acre, preferably an area large enough to fill a car.

Guard rows and shape of plots: As indicated for Preliminary Trial.

2. Semi-Final Trials:

Only varieties which in preliminary trials have shown themselves to be promising should be included in a semi-final trial.

As in the preliminary trial, alternate plots are check plots planted to the standard variety.

Each seedling should be replicated from two to four times. The size of plot may vary from 1/20th to 1/50th acre. The number of replications and size of plot will depend somewhat upon the amount of seed and space available, and upon the degree of promise of the seedling in question.

Fig. 2 illustrates the conventional form of a semi-final test. In this test, Seedlings 1, 2, 3 and 4 are being tested in comparison with alternate check plots of the standard variety. Each of the four seedlings is replicated three times.

As in the preliminary trials, practical considerations may require some changes in detail, but the plan should be followed in principle.

3. Final Trials

Only seedlings which have given a good account of themselves, in both preliminary and semi-final trials should be included in a final trial.

Alternate plots are checks of the standard variety. Each seedling should be replicated from five to seven times. The size of plot may vary from 1/10th to 1/20th acre.

Field Boundary					
Two Guard Rows					
①	②	③	④	⑤	⑥
Sdlg. #1	Check	Sdlg. #2	Check	Sdlg. #3	Check
⑦	⑧	⑨	⑩	⑪	⑫
Check	Sdlg. #1	Check	Sdlg. #2	Check	Sdlg. #3
⑬	⑭	⑮	⑯	⑰	⑱
Sdlg. #2	Check	Sdlg. #3	Check	Sdlg. #1	Check
⑲	⑳	㉑	㉒	㉓	㉔
Check	Sdlg. #2	Check	Sdlg. #3	Check	Sdlg. #1
㉕	㉖	㉗	㉘	㉙	㉚
Sdlg. #3	Check	Sdlg. #1	Check	Sdlg. #2	Check
㉛	㉜	㉝	㉞	㉟	㊱
Check	Sdlg. #3	Check	Sdlg. #1	Check	Sdlg. #2

Fig. 3. Model plan for final trial.

Number of plots: From five to seven of each seedling, alternating with check plots of the standard variety.

Size of plots: From 1/10th to 1/20th acre.

Shape of plots: Necessarily dependent upon contour of field, preferably as nearly square as possible. Very long, narrow plots may be used to good advantage under unirrigated conditions if the outside rows of each plot are discarded as guard rows.



Fig. 4. Final trial in an irrigated field.
Hapa watercourses are discarded.
Each plot is numbered to facilitate identification.

A conventional arrangement is shown in Fig. 3. Here Seedlings 1, 2 and 3 are being compared with alternate checks of the standard variety. Each of the three seedlings is replicated six times.

Fig. 4 shows the adaptation of the conventional plan to an irrigated field.

Under irrigated conditions the locations and boundaries of the plots are determined more or less by the ditches and watercourses. Under unirrigated conditions it is easier to adhere to square plots, regularly placed.

Long narrow plots are also suitable for unirrigated fields with long lines because of their convenience in planting and harvesting. When they are used, however, the outside lines of each plot should be discarded from the experiment when it is harvested, since their yields are likely to be affected either favorably or adversely by the adjoining lines of the neighboring variety.

A single trial with only five to seven replications is, of course, "final" in name only. Final conclusions can only be drawn from a number of such trials carried out in different parts of the area for which the seedling is intended, and over a number of years. More conclusive results could be had in a given experiment

by increasing the number of replications. The results thus obtained, however, might apply only to that particular area and to weather conditions exactly like those experienced during the trial. For this reason the combined results from two trials, each with six replications, and planted in slightly different areas, or in different seasons, are less likely to be misleading than the results from a single trial with twelve replications.

GENERAL CONSIDERATIONS

1. *Location of Variety Tests:*

If variety tests could be placed in areas so uniform that all plots when planted to the same variety would give exactly the same yield per acre there would be no need of replications, and a single check plot of the standard variety would be sufficient.

The first consideration, therefore, in choosing an area for field experiments is uniformity. This is especially important in pot seedling areas and in preliminary trials, for in these cases it is impossible to have replications to help offset the variability.

It is better to delay an experiment until a reasonably uniform area is available than to plant it on a broken, spotty or highly variable area.

W. W. G. Moir has called attention to the fact that it is undesirable to place a variety or fertilizer experiment in an area recently occupied by an experiment involving different varieties or soil treatments.

A second consideration in locating variety tests is that of convenience. They should be so situated and so arranged as to interfere as little as possible with plantation routine in planting and harvesting.

2. *Ratooning:*

Yields from at least one, and preferably two or three ratoon crops, in addition to the plant crop, should be recorded before the experiment is abandoned.

3. *Quality of Seed:*

A good stand on all plots is essential to reliable figures. If the supply of good seed is limited, it is better to reduce the size of plots or the number of replications than to use poor seed or to increase the spacing.

Every effort should be made to have seed of the same kind for all varieties and checks in the test. If body seed is used for the seedlings, body seed of the same age should be used for the checks whenever possible.

Notes should be taken on the stand of each plot within a month or two after planting, so that these facts will be at hand when the yield figures are being considered.

Good seed is often unobtainable for first plantings. Sometimes the seed must be obtained from other localities, with consequent damage in handling. Due allowance must obviously be made in evaluating the results under those conditions. In general, the check plots in first plantings of seedlings from other localities should be used as indicators of soil variability rather than as absolute standards which the seedling must surpass in order to be retained.

4. *Check Plots:*

Whenever we record the yield of a seedling on a given plot, the question arises: "What would the standard cane have yielded had it been growing on that plot?" The nearest approach to an answer to this question can be had from plots of the standard immediately adjacent to this seedling plot.

It is felt that whenever a seedling is planted, a check plot of the standard variety should be planted at the same time and adjoining the seedling. In the absence of replications, check plots afford the only reliable basis of comparison upon which to measure the performance of a seedling.

Even when seedlings are planted out primarily to increase the supply of seed, check plots of the standard are not amiss. Every opportunity should be seized upon to observe the performance of all seedlings which are being carried along. This can only be done satisfactorily when the seedling plots are interspersed with check plots.

5. *Size of Plot:*

In variety testing there are several advantages in small plots of the size indicated, as against larger plots. First, the amount of planting material of the newer seedlings is usually limited. Second, increasing the size of the plot and thus including more area inevitably results in increasing the variability of soil conditions within the experiment.

If seed and space are limited, larger plots can only be had by decreasing the number of replications. This is undesirable. It is obvious that in the long run five 1/20th acre plots checkerboarded with similar plots of the standard variety will give more reliable yield figures than a single pair of plots of 1/4th acre each.

6. *Number of Lines per Plot:*

Under unirrigated conditions, because of the practice of piling the cane from two lines together in the intervening furrow at harvesting time, all plots should contain an even number of lines, whenever possible.

7. *Guard Rows:*

In the earlier trials, with their smaller plots and fewer replications all seedlings cannot be subjected to equal field boundary and level ditch effects. It is, therefore, better to eliminate these effects altogether by means of guard rows. In later tests guard rows along level ditches may be unnecessary if care is taken to see that all seedlings are equally exposed to their effects.

8. *Harvesting:*

All plots must be weighed and analyzed separately. "Lumping" either the cane yields or the juice samples from the different plots of a variety destroys much of the information to be gained through replications.

9. *Staking of Plots:*

It is important that the plots be staked with permanent stakes in such a manner that anyone inspecting the area may identify each seedling at a glance. It facilitates the taking of notes, and stimulates the interest of the plantation personnel in the seedlings.

The plots in the area should be numbered, so that each plot has a distinguishing number which appears both on the map and on the field stake. The plot number, as well as the seedling number, should be recorded in tabulating yields and juice analyses. The plot number serves to locate the exact position in the field of the check plot or replication in question.

10. *Samples for Juice Analyses:*

Yield tests which are otherwise accurate may be rendered false and misleading by inadequate samples for juice analyses. A running sample of the crusher juice from the entire lot of cane as it passes through the mill is probably most satisfactory. If this is unobtainable, a large sample of 150 to 200 pounds from each plot should be used. Samples smaller than this are in great danger of being unrepresentative. Care must be exercised in drawing the sample in order that it may be as nearly a true average as possible in the matter of age and quality. The cane which goes into it should, of course, be drawn from each part of the plot.

11. *Accuracy:*

Errors which would be negligible in large scale field operations may have considerable effect when dealing with small plots. Care must be taken that areas are measured and yields determined with the necessary accuracy.

12. *Interpreting the Results:*

The generally accepted method of arriving at the dependability of figures from yield tests is that of "Student." The method is set forth in a table prepared by Y. Kutsunai, a copy of which may be had from the Station upon request.

SUMMARY

1. We have been basing the selection and elimination of seedlings to too great an extent on appearance.
2. Many of our present seedling areas are laid out in such a manner that they cannot be relied upon to give decisive figures, because they do not include enough check plots to determine whether the high yielding seedlings are so because of inherent superiority or because they are in a favored location.
3. Java does not depend on observation. Instead, it looks to data from yield trials to determine whether a seedling is to be spread or rejected.
4. A program of seedling testing for Hawaii is outlined.

The Hand Refractometer as an Aid in Seedling Selection

BY J. A. VERRET AND A. J. MANGELSDORF

The production of large numbers of new seedlings each year has as its prime object the discovery of a cane which will produce more sugar per acre than those now grown. Because of the fact that it is invisible we are rather prone to forget that the source of our revenue is the *sugar* in the cane—not the cane itself.

It is unfortunate, but nevertheless a fact, that we can form no estimate of the sucrose content of a seedling from its appearance. It is important, therefore, to have a simple and rapid means of estimating the juice quality of the thousands of seedlings examined each season. Without some such means we are compelled to ignore in our early selections the very constituent for which we are breeding.

In the earlier stages of selection (Field Trials 1 and 2) each seedling is represented by a single stool, or by a few feet of line. A method of arriving at juice quality must, therefore, provide a means of obtaining a sample without destroying too much of the cane, for as much seed as possible of the seedlings selected must be saved for planting.

A few months ago Carl Zeiss, Inc., New York, announced a new hand refractometer designed especially for the determination of per cent solids in solution in small samples of beet or cane juice. One was purchased by the Station, and it has proved to be very satisfactory for our purpose.

A brief description is given of the method in which it is used.

The use of the refractometer to form an estimate of juice quality in seedlings is not new. The Manoa Substation is not equipped with a testing mill and laboratory, and Mr. Kutsunai has for some years been using an ordinary laboratory refractometer in arriving at the yields of his Field Trial 2 and Field Trial 3 plots. The new refractometer, however, and certain changes in the manner of sampling, have made it possible to speed up this phase of the work.

The following procedure is now being used in making selections in Field Trial 1. The seedlings are classified, preferably by several judges working independently, into three groups:

1. Those which are outstanding enough to be retained for a second trial regardless of their juice.
2. Those which are to be retained if the juice is satisfactory; and finally,
3. Those which are too poor to consider. No juice samples are taken of this group.

The canes which are placed in the first two groups are numbered and tagged. Small segments are then cut from the five largest stalks in the stool, by means of a light backsaw (dovetailing saw). The saw is equipped with a guard, which determines the depth of the cut. This guard, which greatly facilitates the sampling, was devised by J. P. Martin. With two quick strokes of the saw the segment which serves as a sample is removed from the middle of the stalk and is placed in a vial. As already mentioned, five sticks are so sampled. The vial, with its five samples, is then taken to the portable "field laboratory." Here five drops of juice are expressed from each segment by means of a pair of pliers. The juice is collected in a small crucible, and a single reading is made on the composite sample from the five sticks.

The entire operation consumes less time than is required to describe it. Three men, one cutting the samples, one reading the refractometer, and a third recording the figures, have made 1,500 determinations in seven hours.

The new hand refractometer lends itself to rapid work because, unlike the old laboratory type, the reading is made without any movement of the eyepiece. One



Fig. 1. Sampling a standing stool. (Field Trial 1.) A small segment is cut from each of five sticks by means of a light saw equipped with a guard which determines the depth of the cut. A refractometer reading is then made on the juice, which is expressed from the sample by means of a pair of pliers.



Fig. 2. Portable field laboratory designed by Y. Kutsunai. The juice from the five samples has been collected in a small crucible and is being poured onto the prism of the hand refractometer.



Fig. 3. Making a reading with the hand refractometer in the field.

simply places several drops of the juice on the prism, closes it, and reads the scale at the point where the shadow crosses.

The fact that it is light and compact recommends the new hand refractometer for field work. It is no more difficult to carry than a pair of field glasses. It costs only about one-third as much as the old laboratory model.

The refractometer reading gives, of course, only the per cent solids in solution in the juice. This determination corresponds to the "Brix" of the juice as determined by the spindle hydrometer. The refractometer has been found to be more accurate than the Brix spindle for rapid approximations, because the spindle may be as much as several per cent in error if read before the captured air bubbles in freshly extracted juice have had an opportunity to escape, whereas these bubbles have no perceptible effect on the refractometer reading.

The objection might be raised that per cent solids without any knowledge of purity is an inadequate basis on which to judge the quality of the juice. Studies on the relation between per cent solids (Brix) and quality ratio in a large number of seedlings are reported in detail in another paper in the present issue of the *Record*. It need only be mentioned here that these studies show a close relationship not only between per cent solids and sucrose, but also between per cent solids and purity, resulting in a very high correlation between per cent solids and quality ratio. The relationship is sufficiently close to warrant the use of per cent solids as determined by a refractometer reading in forming a preliminary estimate of juice quality in the early stages of selection.

The method of sampling described has the advantage that the sticks from which the samples are taken are left standing and may be used as a source of seed. A certain percentage of them may blow over if subjected to wind, but unless broken off entirely, which rarely happens, they continue to live indefinitely.

Various means of removing a small sample from the stalks were tried before the backsaw method was adopted. This method is rapid and positive, but there is still room for improvement. It should be possible to devise an instrument which will remove a sample without severing so much of the rind, and, therefore, with less danger of the stick breaking following sampling.

Some such method, if perfected, should prove useful as a means of obtaining pre-harvest samples of fields which are being ripened off. It is possible that even the present backsaw method of sampling would answer the purpose. It would seem that a sample composed of sections cut from a large number of sticks should be more representative than a few sticks. In the time required to cut a five-stick sample and carry it out of the field, several hundred sticks could be sampled with a backsaw. The sampler would need to be provided with a suitable container into which the segments could be dropped quickly and in which they would be protected from evaporation. When a sufficient number had been collected the juice could be expressed by means of a small press. Several hundred segments should yield enough juice for Brix, polarization and glucose determinations. It is planned to try this method of pre-harvest sampling on a field scale the coming season.

SUMMARY

1. In the early stages of selection, where thousands of seedlings are dealt with, a rapid means of estimating juice quality is needed.
2. Per cent solids (Brix) has been shown to be highly correlated with quality ratio, and may, therefore, be relied upon to give a good estimate of juice quality.
3. A rapid method of sampling standing cane and of determining per cent solids by means of the new hand refractometer is described.

Notes on Irrigation Investigations and Control at Makee Sugar Company

BY H. R. SHAW

PLANTATION IRRIGATION EQUIPMENT

Supply: Mountain flow supplies the irrigation water for the Makee plantation. The plantation develops from 300 to 600 million gallons of water per month from stream and storm ditch sources, and purchases approximately 7,500 million gallons per year from other sources outside the plantation.

One combination Diesel centrifugal pump with a six million gallon capacity pumps the mill discharge water to the upper levels of the plantation for use in irrigation.

Field Layout: The plantation practices the usual Hawaiian furrow system of irrigation. Although there is no standard practice as to the number of lines irrigated as a unit, the two-line "U" system is generally used. Watercourses are 35 feet wide, and furrows are 5 feet wide from center to center.

Survey: All fields are gross acreage with the boundary 3 feet out from the actual cane boundary. Watercourse surveys are from center of watercourse to center of watercourse and from center of level ditch to center of level ditch.

Ditch Lining: None of the plantation ditches are lined, and as yet no seepage tests have been made.

WATER MEASUREMENTS

Control: The staff conducting irrigation measurements, investigations and control consists of one man in charge, one clerk, and two men who handle growth measurements, repair and maintenance of meters, and assist in harvesting experiments. Meter readings are submitted by the section overseers from data supplied by the field ditchmen. The ditchmen also make all adjustments and changes of orifice gates.

Equipment: Weirs with Stevens Water Stage Registers measure the water in the main supply ditches. Rated sections are used in sections where it is impossible to install weirs.

Forty Great Western (Lyman) meters are used in all field installations. Redwood installations with depressed "V" basins with a 14-inch drop, 36-inch flat bottom, and 18-inch clearance at both ends, are rapidly taking the place of the flat-bottomed installations previously used.

J. M. Watt, assistant manager, and formerly in charge of irrigation investigations at Ewa, Lihue, Koloa and Makee, is one of the strongest advocates of the Great Western meter in the Islands. He says: "This meter is adapted to a certain purpose, and when used under the conditions required and for the purpose intended, it will give excellent results. It is not built for registering high fluctuations in head, and a flow recorder should supplement the meter on main supply canals. For measuring total water to the fields, however, it is decidedly preferable to any other device on the market. Its main advantages are: simplicity of construction, ease of operation, sensitiveness, portability, and the fact that only a small quantity of the total flow is required to pass through it, thus allowing easy screening. From an exhaustive series of tests in field installations and against standard rectangular weirs, I have found that the Great Western meter will check to within 3 per cent, which is all that is necessary to supply a working average on water distribution, man capacity, and other factors of interest to the plantation."

IRRIGATION INVESTIGATIONS

Policy: The general policy of the plantation management in regard to irrigation investigations is to expand the program of complete metering of the plantation as rapidly as possible, supplemented by a limited amount of experimental work. Makee also plans to establish an irrigation control system.

Irrigation Experiments: The area of the plantation under irrigation control is as follows:

	1927 Crop	1928 Crop	1929 Crop
Experiments.....	134.12	76.56	98.06
Total Application.....	227.95	735.64	530.05

Irrigation experiments are based on the interval between irrigations. Three general series of treatments are given, depending on the soil and climatic conditions:

Day Interval		
Maximum	Normal	Minimum
7	14	21
10	17	24
10	20	30

Each treatment is applied to level ditch plots with three repetitions in each experiment. Net water is measured at the head of the level ditch, growth measurements are taken on at least 25 stalks in each level ditch plot.

During the second season growth period, Makee employs a ripening schedule with gradually lengthening intervals for each treatment. The harvesting date and date of last irrigation are predetermined, and a ripening schedule for each treatment is so designed that at the last irrigation all plot treatments have the same interval of 24 days.

According to Mr. Watt, a reasonable interval schedule for Makee conditions would be:

Short Crop

From start of crop to following September—10-day interval (max.).

From September to November—17-day interval (normal).

From November to March—24-day interval (min.).

From March to cessation of irrigation—17-day interval with gradually increasing interval up to start of ripening period.

Long Crop

Same as for short crop, except that the maximum treatment would continue through the summer of the second season before applying the ripening schedule.

Experimental Results: Harvesting results from the irrigation experiments tend to confirm conclusions drawn by other plantations on the Island:

1. Cane tonnage generally increases with the amount of water applied. With heavy applications, however, the yield is not in proportion to the units of water per unit cane.

2. The more rapid and uniform the irrigation the better the results in growth and total sugar.

3. The longer the interval the less acreage covered by each irrigator per day, and the greater amount of water consumed per acre.

4. In general, the response of growth to frequent applications of water is not as marked in the second growth season as in the first.

Seedling Selection Studies—I

INTERRELATIONSHIPS BETWEEN BRIX, PURITY AND QUALITY RATIO

BY J. A. VERRET AND A. J. MANGELSDORF*

In Field Trial 1, each seedling is represented by a single stool and in Field Trial 2 usually by only a few feet of line. Thousands of seedlings have to be dealt with in these early stages of selection before the process of elimination has reduced their numbers.

* Thanks are due Royden Bryan, J. F. Jensen, Asao Doi and R. H. Rice for assistance in tabulating the data and making calculations.

Because of the fact that there is only a small amount of each seedling, and because there are so many to be examined, a complete analysis to determine the quality of the juice is hardly feasible. Brix determinations on small samples have therefore been resorted to as a means of estimating the juice quality of the seedlings in these early stages of selection.

In order to form an opinion as to whether a Brix determination is a sufficiently reliable basis on which to estimate quality ratio under these circumstances, the complete juice analyses of several thousand different seedlings were examined statistically, in order to determine (1) the relation between Brix and purity and (2) the relation between Brix and quality ratio. The findings are presented below:

BRIX AND PURITY

The term "Brix" is used throughout in referring to per cent solids in solution, whether determined by a Brix spindle or by a refractometer.

Purity refers, of course, to the percentage of sucrose in the total solids in solution.

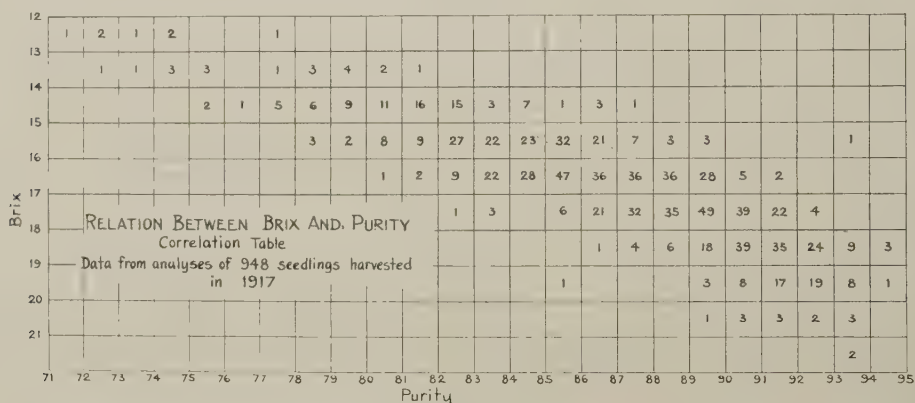


Fig. 1

We were surprised to find that a very high positive correlation exists between Brix and purity. Fig. 1 shows a correlation table setting forth the relationship between these two variables in a group of 948 seedlings harvested at Makiki in 1917. It will be noted on referring to the illustration that at 13 to 14 Brix, for example, the purity ranges from 72 to 82, while at 20 to 21 Brix the purity ranges from 89 to 94. The coefficient of correlation between the two was found to be $+ .82 \pm .007$. The coefficient of correlation is useful only in so far as it enables us to visualize from a single figure (with its probable error) the relationship existing between two sets of values, each set containing perhaps several hundred items.

It will be remembered that a coefficient of $+ 1.0$ indicates complete positive correlation, i.e., with the two variables increasing in exactly the same proportions; that a coefficient of 0 indicates that the two variables behave quite at random towards each other, and that a coefficient of $- 1.0$ indicates complete negative correlation, the one value increasing proportionately to the decrease of the other.

In the case under discussion, therefore, the correlation is a very close one, especially in view of the small probable error.

The coefficient of correlation between Brix and purity was calculated for two other groups of seedlings also, with the following results:

644 seedlings harvested in 1918..... $+ .72 \pm .01$
 492 seedlings harvested in 1921..... $+ .85 \pm .008$

It will be noted that for these two groups also the coefficients of correlations are very high, with small probable errors.

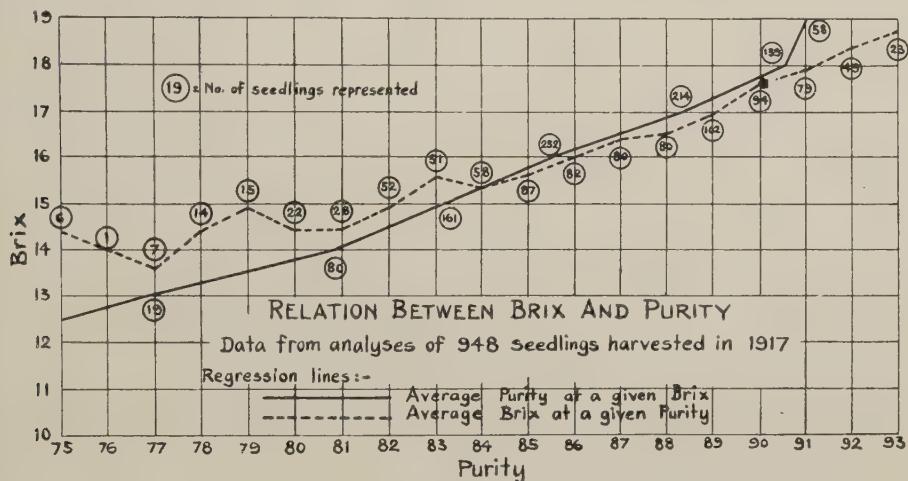


Fig. 2, dealing with the same group of seedlings as Fig. 1, sets forth in a different manner the relationship between Brix and purity. The broken line gives the average Brix at a given purity, the solid line the average purity at a given Brix. If the correlation were perfect the two lines would coincide. It will be observed that they do, in fact, follow very nearly the same course.

It is not obvious why there should be such a close correlation between Brix and purity. It is conceivable that canes with a high percentage of solids in solution might have, on the average, just as large a proportion of those solids in the form of non-sucrose materials as those with a small percentage of solids. Such, however, is not the case. The greater the percentage of solutes in the juice, the greater the proportion of sucrose to impurities.

It would not have been so surprising to have found a definite relationship of this kind among a number of analyses of a single cane, say H 109. We did not anticipate its existence, however, within a group of miscellaneous seedlings involving a number of parentages.

That a similar relationship to that just described also holds within a single variety was shown by a study of juice analyses of 947 stools of H 109 cane harvested at Waipio in 1927. The coefficient of correlation between Brix and purity was found to be $+ .65 \pm .01$. This correlation, it will be observed, is less pronounced than for the three groups of data already discussed, each member of

which was a different seedling. Why the correlation within a single variety should have been lower than among different seedlings, we are unable to explain, unless it is that conditions are more variable in Field 21, Waipio, where the H 109 stools were grown, than at Makiki where the miscellaneous seedlings were grown.

BRIX AND QUALITY RATIO

That a certain amount of correlation between Brix and quality ratio must inevitably exist is obvious, since a juice with a low Brix cannot have a high percentage of sucrose.

This fact, together with the further finding, already discussed, that a low Brix tends very definitely to be associated with a low purity, made it appear likely that the correlation between Brix and quality ratio is a high one.

This was found to be the case in the three groups of seedlings examined, as will presently be shown.

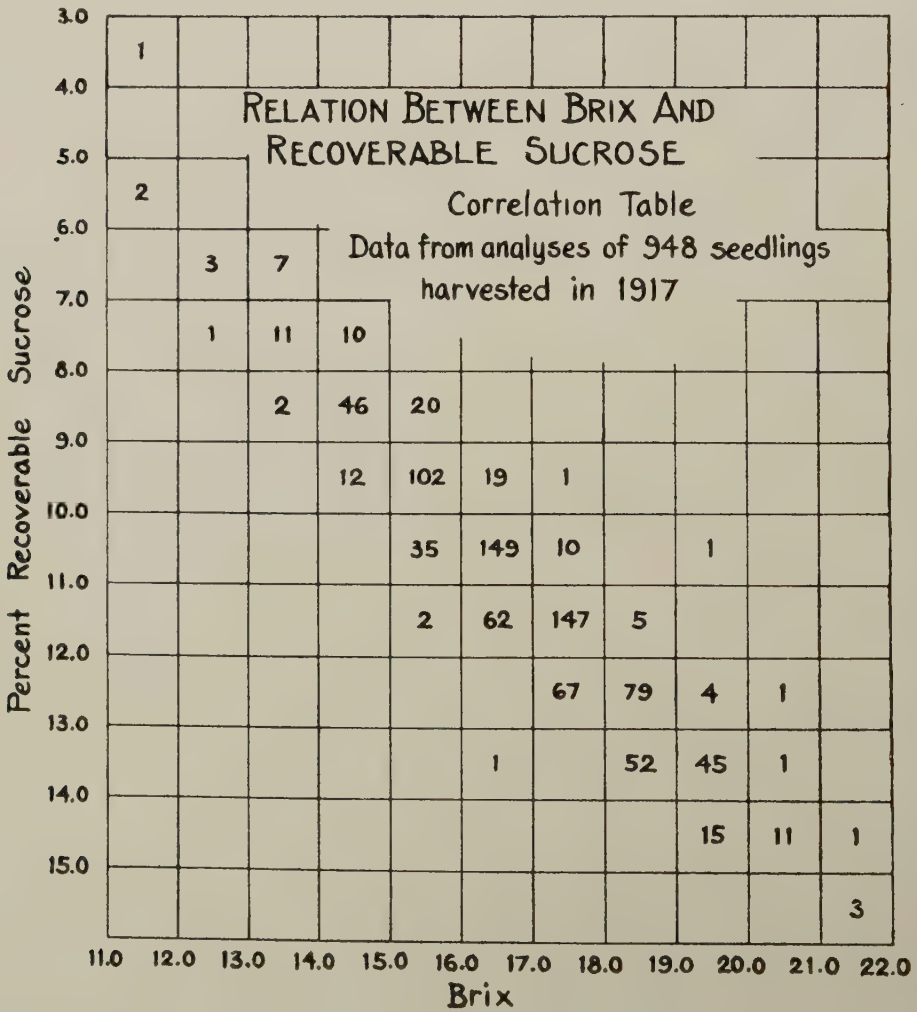


Fig. 3

For plotting purposes, quality ratio must be converted into its reciprocal, per cent recoverable sucrose, because a unit of quality ratio is not a constant one. A difference of a point at a quality ratio of 6.0 is twice as large in terms of per cent sugar as a difference of a point at a quality ratio of 12.0. In these studies quality ratios have therefore been converted into per cent recoverable sucrose for the sake of accuracy in plotting.

Fig. 3 shows the relation between Brix and per cent recoverable sucrose among the 948 seedlings harvested in 1917. It is obvious from the distribution of the values on the illustration that the correlation is very close. A given Brix tends to have a definite per cent recoverable sucrose, with but little departure in either direction.

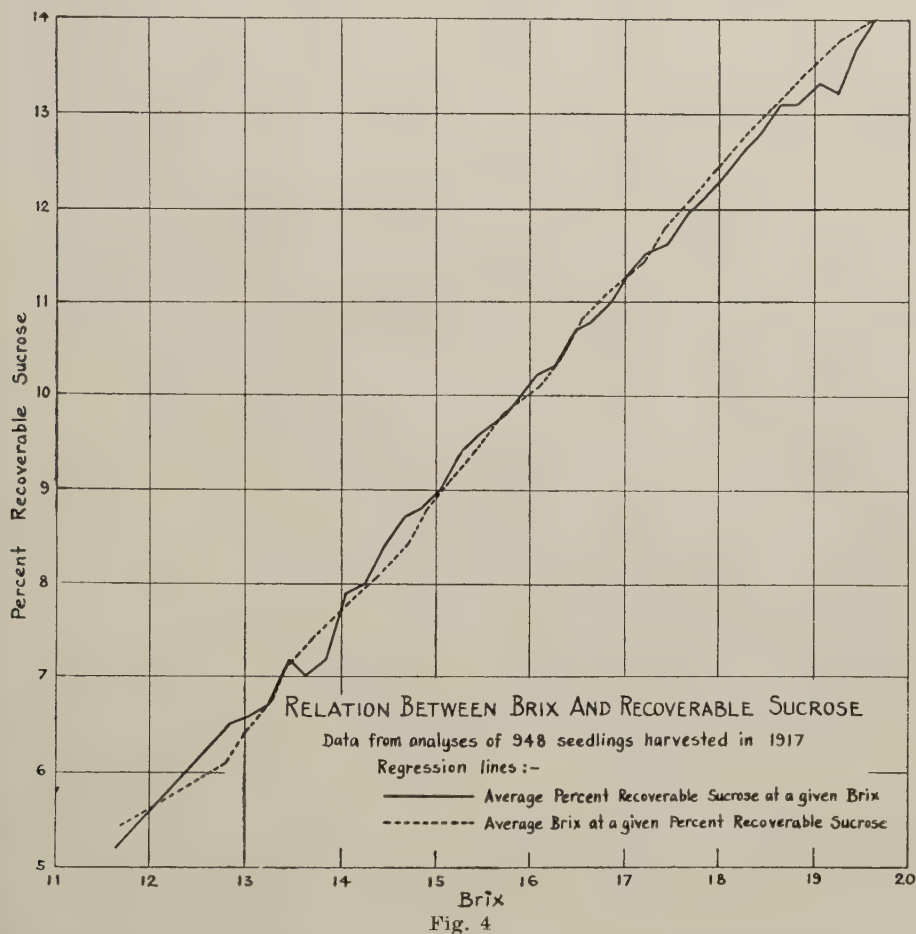


Fig. 4, showing (1) the average Brix at a given per cent recoverable sucrose and (2) the average per cent recoverable sucrose at a given Brix, affords further evidence of the closeness of the correlation, since the two lines almost coincide.

The coefficients of correlation between Brix and per cent recoverable sucrose were calculated for the groups of analyses under discussion and were found to be as follows:

948 seedlings harvested in 1917.....	+ .967 \pm .001
644 seedlings harvested in 1918.....	+ .974 \pm .008
492 seedlings harvested in 1921.....	+ .925 \pm .004
504 stools of H 109 harvested in 1927.....	+ .875 \pm .006

The above figures indicate that the correlation between Brix and quality ratio is extremely close.*

As was the case with the Brix-purity relationship, the correlation was not so intense within a number of analyses of a single variety as it was between various seedlings. We cannot but believe that this is a peculiarity of the particular group of H 109 analyses under observation, rather than a general rule.

We feel more secure, since completing the calculations reported above, in using Brix as a means of estimating quality ratio under circumstances which render complete analyses impracticable. It is true that it gives only an approximation, and where a complete juice analysis is possible, the latter is of course to be preferred. However, it is reassuring to know that where Brix determinations must be resorted to, they may be relied upon to give a very good indication of juice quality.

CONCLUSIONS

1. A complete juice analysis of each seedling is not practicable where many thousands have to be examined.
2. An examination was made of the analyses of about 2000 seedlings to determine whether under such circumstances Brix is a safe basis on which to estimate juice quality.
3. A very close positive correlation was found to exist between Brix and purity; the higher the Brix, the higher the purity.
4. This relationship between Brix and purity, together with the fact that the major component of Brix is sucrose, results in an extremely close positive correlation between Brix and quality ratio.
5. It is concluded that in cases where a complete juice analysis is not feasible, a Brix or refractometer reading affords a fairly reliable basis on which to estimate juice quality.

Nitrification as a Measure of Soil Fertility

BY W. T. McGEORGE

During the past fifteen years fertilizer programmes on our island plantations have undergone rather extensive modification and there is no question but that a more intelligent fertilizer practice is in large part a factor in our steadily increasing

* This, of course, refers to normal cane and not to cane which has gone back from drying out too much.

sugar production. In formulating these modifications in the fertilizer programme, field experiments have played a major role, as has also the chemical analysis of the soil. Useful correlations have been established for estimating the potash and phosphate requirements of our cane lands by laboratory examination. But this is not true for the nitrogen problem. With this highly important nutrient entire dependence upon field experiments has been the rule, it being generally assumed that all our soils are in need of readily available forms of nitrogen and that it is largely a problem of "trial and error." Less attention has therefore been given to correlation between cane yields and laboratory methods of estimating nitrogen availability. This does not mean that nitrogen studies on Hawaiian soils have been overlooked, for Kelley as well as Burgess devoted considerable time to the nitrogen problem and they have recorded somewhat extensive observations.

Recently there appeared in *Mededeelingen van het Proefstation voor de Java-Suikerindustrie* (No. 3, 1928) an article by Dr. O. Arrhenius on the "Nitrogen Question in the Java Sugar Industry." From this article it appears that Arrhenius has established a correlation between the nitrate-producing power of Java soils and their fertility. He has approached his problem somewhat in the same manner by which we established our correlation between potash and phosphate availability and field performance, namely, by studying soils selected because of their known response under field conditions. By determining the nitrifying power of soils taken from a large number of field tests (ammonium sulphate seems to be the most extensively used source of nitrogen in Java) he suggested the following relation: When the nitrate production of the soil is below ten parts per million all experiments give positive response and a high ammonium sulphate application is necessary. The higher the nitrifying power of the soil the less will be the amount of ammonium sulphate required to produce the maximum crop beyond which the soil no longer responds.

At the time this article appeared in print, W. P. Alexander was in the midst of an extensive study and summary of six years of nitrogen experiments at Ewa Plantation Co., comprising some seventy-four tests in twenty-nine different fields. In view of Arrhenius' observations in Java, he submitted soil samples to the Experiment Station, requesting similar data on the twenty-nine Ewa fields. The information obtained from this study is presented for its general interest.

NITRIFICATION AND SOIL FERTILITY

The attempt to correlate crop performance with biological activities in soils is by no means new. The soil microflora, the bacteria and fungi, are plants with plant food requirements similar to the higher plants, but with probably more active foraging properties. They consume available forms of plant food, and, to a less extent, difficultly available nutrients. Indirectly or directly, they are capable of widely varying associative reactions toward the higher plants. The nodule-forming bacteria growing in symbiosis with leguminous plants are cases in point and illustrative of many more such associations found in nature. Of the beneficial soil organisms, those fixing nitrogen from the air, those changing organic forms of nitrogen into ammonia or into nitrate, those producing carbon dioxide, and more

recently the sulphofying organisms which change organic or inorganic sulphur into sulphate, are most common. For this reason attempts to correlate biological activities with soil fertility largely involve one or more of the above. The life cycle of such organisms is relatively short, and their death and decay in large numbers should make for highly available forms of the nutrients which they have absorbed for their own subsistence. On the above basis it is not unreasonable to anticipate better fertility where biological activities are at optimum. A number of investigators, both in the United States and Europe, have devoted considerable time to such problems. In Iowa, Pennsylvania and California, for example, investigations have shown a direct relation between nitrification and ammonification and crop production. In fact, Burgess, in 1918, made such a study of our plantation soils with results which led him to conclude:

1. Ammonification tests are not suitable to differentiate between the fertilities of average Hawaiian soils, although they will often show differences between very poor and very good soils.

2. Nitrification is by far the most accurate biological soil test yet perfected for predicting probable soil fertility. In fact, it is probably the best single test of any description yet developed for ascertaining the crop-producing powers of arable soils. At least this holds for Hawaiian soils. * * * In only a very few instances have the nitrification coefficients been at variance with the known fertility of the fields from whence the samples are taken. Of course there are exceptions, and it must not be inferred that nitrification tests are able to take the place of carefully conducted chemical or vegetation experiments. Active nitrification may not be the cause of high fertility, yet those conditions which tend to promote active nitrification are very evidently identical with those which tend to give us enhanced crop yields. Furthermore, although nitrification tests may be a means of differentiating between good and poor soils, they do not tell us of the causes of the differences noted, nor do they show us exactly how to improve conditions in soils of low productivity.

Probably the most extensive study of soil biology as related to fertility is that given in a recent series of papers by S. A. Waksman of the New Jersey Experiment Station. His investigations involved the relation of bacterial counts, ammonification, nitrification, carbon dioxide evolution, rate of cellulose decomposition and nitrogen fixation. His comments on nitrification are of interest:

Soil microbiological research has not yet gone far enough to justify our using any soil microbiological factor as an index of soil productivity. Nevertheless, the author feels justified in pointing out that the data submitted, together with those published previously, bring out certain correlations, which may help in time to place in our hands quantitative as well as qualitative methods for measuring the productive power of soils.

The results presented in this paper on the nitrifying power of the soil indicate that nitrification studies can yield information for the differentiation of soil fertility * * *. However, since soil fertility is affected, aside from the biological activities of the soil, also by its physical and chemical conditions, the results should not be expected to be a mathematical function of crop productivity of a given soil.

EXPERIMENTAL

In order to make the data as complete as possible, the nitrification tests were made a little more thorough than is usually necessary. The soil samples were

taken by the plantation and sent early next morning to the Experiment Station. The nitrate content of a soil, as well as its nitrifying power, will usually be altered by drying the soil in the air. For this reason part of the tests were made on the soils just as they came from the field—that is, no drying out. The following is an outline of the examination:

1. The nitrate content of the soil was determined on the same day the sample was received in the laboratory—within 24 hours of the time the sample was taken.
2. The fresh soil was brought to optimum moisture content and incubated at 26°—room temperature—for 28 days.
3. The fresh soil to which ammonium sulphate was added was incubated as in 2.

The soils were then dried in the air and three further sets prepared for incubation.

4. Soil—as is—brought to optimum moisture content.
5. Ammonium sulphate added and brought to optimum moisture content.
6. Dried blood was added and the soil brought to optimum moisture.

The nitrate content of the incubated soils was then determined at the end of the 28-day incubation period by the phenoldisulphonic acid method. The first would give us a knowledge of the nitrate content of the soil in the field and therefore tell us something of the nitrification under field conditions. The second would tell us of the nitrifiability of the soil nitrogen under optimum conditions—good aeration and optimum moisture. The third would tell us of the power of the soil to nitrify ammonium sulphate. Four and 5 would give the same information as 2 and 3 after the soils had been air-dried, and 6, the nitrifying power of the air-dried soil for blood. Ammonium sulphate was added at the rate of .04 gram per 100 grams of soil, and blood at the rate of .06 gram per 100 grams of soil. Moisture was added to the soils each week to replace that lost by evaporation. The data are given in Tables I to V and shown graphically in Figs. 1 to 3. Qualitative tests were also made for nitrites, and the relative content indicated in the tables in approximation by *o* for absence, *t* for very faint test, and *+* marks for positive, with the relative amounts shown by the number of *+* marks.

TABLE I
NITRIFICATION IN FRESH SOIL
(Parts per mil. N in dry soil)

Soil No.	Total N	After Incubation NasNO ₃	Before Incubation NasNO ₃	Formed During Incubation NasNO ₃	Per cent N Nitrified	Nitrites
1	970	14.4	5.4	9.0	.93	0
2	1260	8.3	2.8	5.5	.44	t
3	860	1.7	2.7	0	0	0
4	830	10.6	4.0	6.6	.79	t
5	1670	11.7	4.0	7.7	.46	0
6	1250	10.3	3.9	6.4	.51	0
7	1670	11.5	4.2	7.3	.44	+
8	1680	18.4	5.6	12.8	.76	+
9	1440	6.9	7.0	0	0	+
10	1590	8.5	2.7	5.8	.34	+
11	640	2.8	2.0	.8	.12	0
12	1160	7.5	2.6	4.9	.42	0
13	730	2.2	3.4	0	0	+
14	1160	23.0	13.6	9.4	.81	+
15	1230	22.2	19.8	2.4	.19	+
16	1180	14.6	7.3	7.3	.62	+
17	1410	22.9	22.4	.5	.03	+
18	1300	6.8	3.5	3.3	.25	0
19	1370	17.4	3.6	13.8	1.01	+
20	1100	7.9	4.2	5.7	.52	+
21	3500	30.0	5.1	24.9	.71	+
22	1620	16.0	4.9	11.1	.68	+
23	1700	23.0	14.0	9.0	.53	+
24	1680	9.1	2.7	6.4	.38	+
25	1800	4.6	2.0	2.6	.14	+
26	2100	7.7	2.8	4.9	.23	+
27	1800	12.2	2.7	9.5	.53	+
28	1780	20.6	3.7	16.9	.95	+
29	1840	5.5	2.7	2.8	.15	+

TABLE II

NITRIFICATION OF AMMONIUM SULPHATE IN FRESH SOIL

Soil No.	N Added as (NH ₄) ₂ SO ₄	(Parts per mil. N in dry soil)			Nitrites
		After Incubation N as NO ₃	After Incubation N as NO ₃ in Blank	Difference N as NO ₃	
1	84.8	134	14.4	120	+
2	"	114	8.3	106	+ +
3	"	112	1.7	110	+
4	"	118	10.6	107	+
5	"	112	11.7	100	+ + +
6	"	108	10.3	98	+
7	"	121	11.5	100	+
8	"	122	18.4	104	+
9	"	120	6.9	113	+ +
10	"	118	8.5	110	+
11	"	118	2.8	115	+
12	"	123	7.5	116	+
13	"	106	2.2	104	+
14	"	116	23.0	93	+ +
15	"	114	22.2	92	+
16	"	123	14.6	108	+
17	"	132	22.9	109	+
18	"	107	6.8	100	+
19	"	105	17.4	88	+
20	"	127	7.9	119	+
21	"	138	30.0	108	+
22	"	127	16.0	111	+
23	"	131	23.0	108	+
24	"	119	9.1	110	+
25	"	119	4.6	114	+
26	"	118	7.7	110	+
27	"	114	12.2	102	+
28	"	140	20.6	119	+
29	"	66	5.5	61	+ + + +

TABLE III
NITRIFICATION IN AIR-DRY SOIL

(Parts per mil. N in dry soil)

Soil No.	Total N	After Incubation N as NO_3	In Soil N as NO_3	Formed During Incubation N as NO_3	Per Cent Soil N Nitrified	Nitrites
1	970	27	5.4	21.6	2.2	0
2	1260	19	2.8	16.2	1.3	+
3	860	13	2.7	10.3	1.2	+
4	830	20	4.0	16.0	1.9	+
5	1670	29	4.0	25.0	1.5	+
6	1250	28	3.9	24.1	1.9	+
7	1670	23	4.2	18.8	1.1	+
8	1680	39	5.6	33.4	2.0	+
9	1440	22	7.0	15.0	1.0	t
10	1590	22	2.7	19.3	1.2	t
11	640	17	2.0	15.0	2.3	0
12	1160	22	2.6	19.4	1.7	0
13	730	16	3.4	12.6	1.7	t
14	1160	44	13.6	30.4	2.6	+
15	1230	50	19.8	30.2	2.4	+
16	1180	31	7.3	23.7	2.0	+
17	1410	53	22.4	30.6	2.2	+
18	1300	23	3.5	19.5	1.5	+
19	1370	23	3.6	19.4	1.4	+
20	1100	28	4.2	23.8	2.2	+
21	3500	51	5.1	45.9	1.3	+
22	1620	30	4.9	25.1	1.5	+
23	1700	35	14.0	21.0	1.2	+
24	1680	29	2.7	26.3	1.6	+
25	1800	32	2.0	30.0	1.7	+
26	2100	24	2.8	21.2	1.0	+
27	1800	29	2.7	26.3	1.4	+
28	1780	42	3.7	38.3	2.2	+
29	1840	12	2.7	9.3	.5	+

TABLE IV

NITRIFICATION OF AMMONIUM SULFATE IN AIR-DRY SOIL

(Parts per mil. N in dry soil)

Soil No.	N Added as (NH ₄) ₂ SO ₄	After Incubation N as NO ₃	Blank N as NO ₃	Difference	Nitrites				
1	84.8	133	27	106	+	+	+	+	+
2	"	123	19	104	+				
3	"	81	13	68	+	+	+	+	
4	"	93	20	73	+	+			
5	"	106	29	77	+	+			
6	"	108	28	80	+	+			
7	"	104	23	81	+	+			
8	"	125	39	86	+				
9	"	112	22	90	+				
10	"	105	22	83	+				
11	"	114	17	97	+	+	+		
12	"	118	22	96	+				
13	"	95	16	79	+	+	+		
14	"	144	44	100	+				
15	"	145	50	95	+	+	+		
16	"	106	31	75	+	+	+	+	
17	"	158	53	105	+				
18	"	108	23	85	+	+			
19	"	104	23	81	+	+	+		
20	"	106	28	78	+	+	+	+	
21	"	97	51	46	+				
22	"	106	30	76	+	+	+	+	
23	"	105	35	70	+	+	+	+	
24	"	111	29	82	+				
25	"	109	32	77	+				
26	"	113	24	89	+	+			
27	"	112	29	83	+	+			
28	"	117	42	75	+	+			
29	"	81	12	69	+	+			

TABLE V
NITRIFICATION OF BLOOD IN AIR-DRY SOIL

(Parts per million N in dry soil)

Soil No.	N Added Blood	After Incubation N as NO ₃	Blank N as NO ₃	Difference	Nitrites
1	84	147	27	120	+
2	"	100	19	81	+
3	"	89	13	76	+ +
4	"	91	20	71	+ +
5	"	90	29	71	+ +
6	"	96	28	68	+ + +
7	"	94	23	71	+ +
8	"	138	39	99	+ + +
9	"	105	22	83	+
10	"	95	22	73	+
11	"	133	17	116	+
12	"	127	22	105	+
13	"	82	16	66	+ +
14	"	87	44	43	+ +
15	"	81	50	31	+ +
16	"	100	31	79	+ + +
17	"	94	53	41	+
18	"	94	23	67	+
19	"	86	23	63	+ + +
20	"	86	28	58	+ + + +
21	"	122	51	71	+ +
22	"	113	30	83	+ +
23	"	103	35	68	+ +
24	"	101	29	72	+ +
25	"	85	32	53	+ + +
26	"	94	24	70	+ +
27	"	93	29	64	+ +
28	"	106	42	64	+ +
29	"	84	12	72	+ +

In Table I is given the total nitrogen present in the soil, nitrate nitrogen present after incubating the fresh soil for 28 days, from which is also subtracted the nitrate nitrogen present in the soil, giving that formed by the nitrification of the soil nitrogen. This has been calculated, too, on the basis of per cent soil nitrogen nitrified. Table III gives similar data obtained on the same soils which were air-dried before incubation. These data are shown graphically in Figs. 1 and 2.

These data show a wide variation in the nitrifying power of Ewa soils as measured by their ability to nitrify their own nitrogen. Three soils, Nos. 3, 9 and 13, showed no nitrification during the period of incubation. Nitrification was greatly enhanced by drying the soils before incubation.

In Table II is shown the nitrifying power of the soils for ammonium sulphate, using the fresh soil, and in Table IV the same after drying the soil in the air. The nitrifying power of the fresh soil for this salt of nitrogen is excellent in all cases except soil No. 29. The effect of drying the soil was to lower the rate of nitrification of ammonium sulphate. In most cases with the fresh soil, and in a lesser number of air-dried soils, the presence of ammonium sulphate appears to stimulate additional nitrification of the soil nitrogen.

In Table V is shown the nitrifying power of the soil for the nitrogen of blood. This nitrogen, like the organic nitrogen in the soil, must first be ammonified before nitrification. With few exceptions nitrification of blood is less than that of ammonium sulphate. This would indicate some variation in the ammonifying power of these soils.

In this graph the tons cane per acre per month are shown with the nitrification data, but, as in the other graphs, there does not appear to be any correlation.

SOLUBLE SALTS IN THE SOILS

In view of the fact that there is a wide variation in the saline content of Ewa soils, the soluble salt content of all twenty-nine samples was determined, but the data are omitted since there was no correlation with nitrifying power.

DATA ON SOIL SAMPLES

Since biological activities are greatly influenced by soil characters and properties, Mr. Alexander very kindly supplied rather extensive data upon the fields from which the samples were taken and these are given in Table VI.

Nitrification of Soil Nitrogen in Percent of Soil Nitrogen Nitrified

										Air dry soil					Fresh soil								
-	0-	+	0	00	--	0	0	00	-	000	+	0	-	-	0	0	-	0	+	+	+	0	Response 300 N over 250 N
+	+	+	+	+	00	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	250 N over 200 N
+	0	+	0	0	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	232 N over 155 N
																							200 N over 150 N

Air dry soil

 Fresh soil

- Negative Response - Loss
 0 No Response
 + Positive Response - Gain

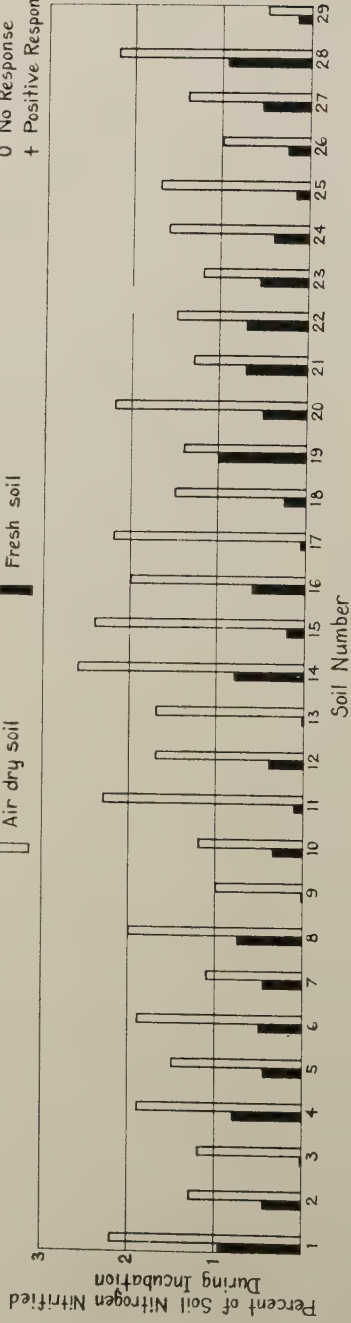


Fig. 1

Response 300 N over 250 N
 " 250 N over 200 N
 " 232 N over 150 N
 " 200 N over 150 N

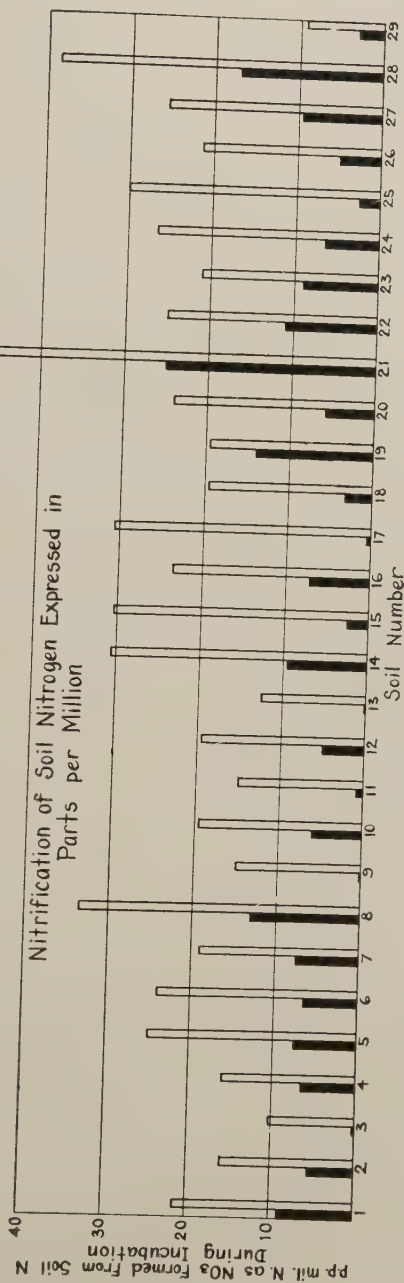


Fig. 2

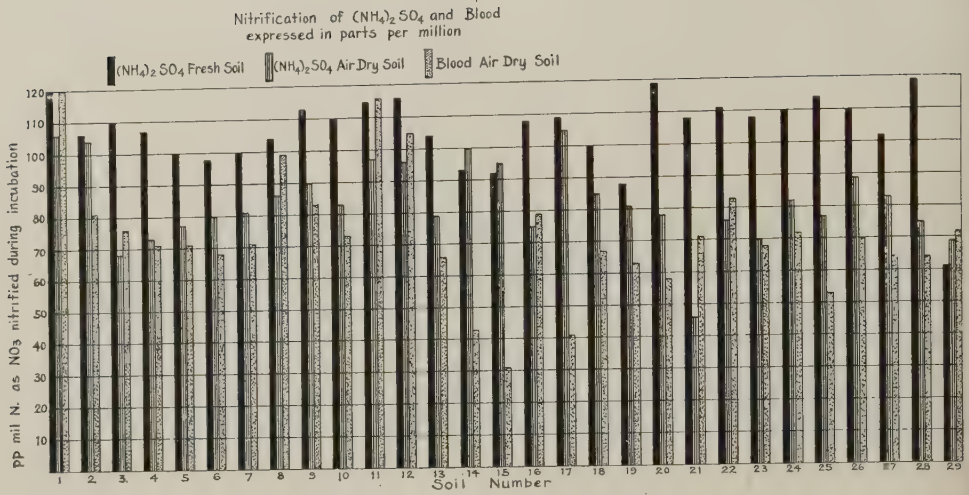


Fig. 3

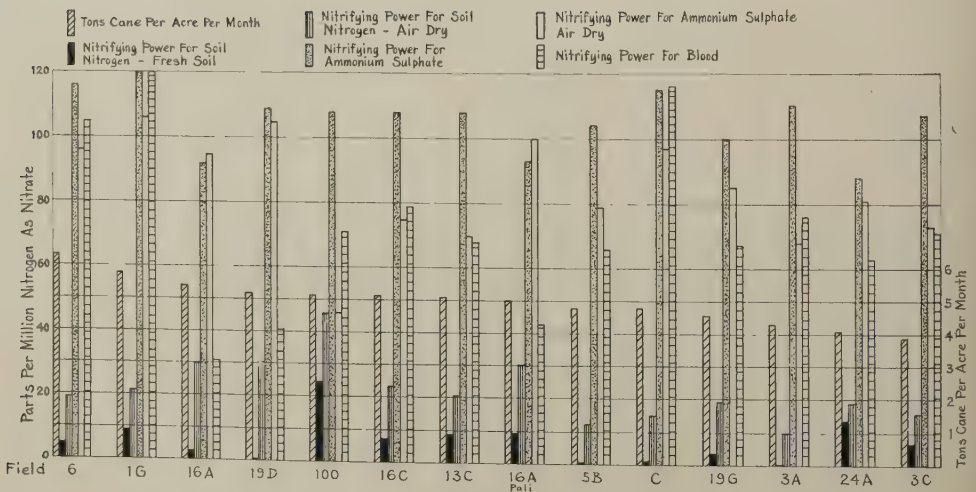


Fig. 4

TABLE VI

Data on Fields Where Soil Samples Were Taken from Nitrogen Experiments—May 16, 1928

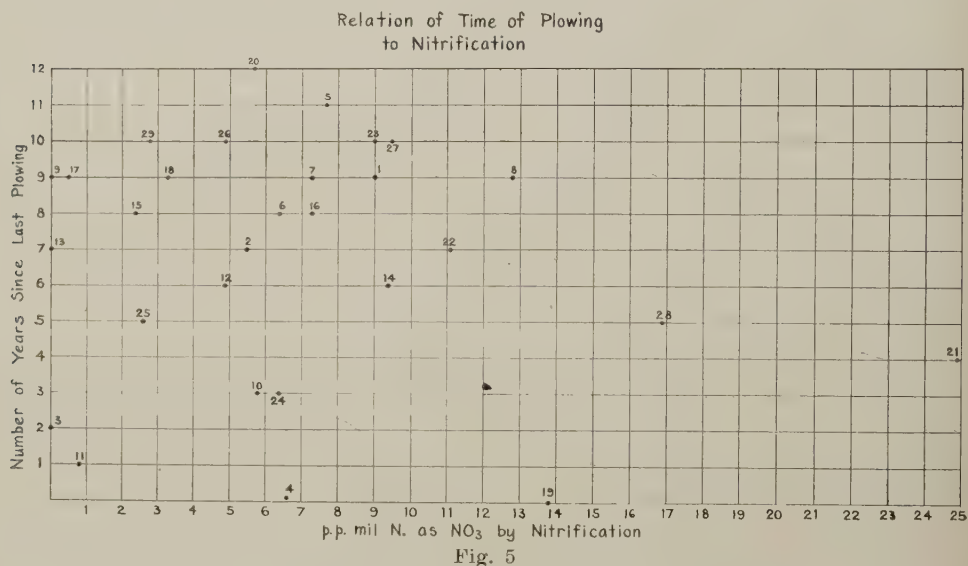
First Foot Depth

Sample No.	Field	Date Sampled	Last Plowing	Last Fertilizer (75-100 lbs.)	Crop Pl. or Rat.	Age of Cane	Character of Soil	Color of Soil
1	1G	May 14/28	1919	Mar. 31/28	1929	5th	Heavy clay	Blackish grey
2	2A	"	1921	June 15/27	1928	Sh. (3)	Silty clay loam	"
3	3A	"	1926	Apr. 26/27	1930	1st	Heavy clay	"
4	3C	"	1928	Apr. 5/27*	1930	Plant	Silty clay loam	"
5	23A	"	1917	June 17/27	1928	Sh. (5)	Silty clay loam	Red
6	23B	"	1920	Feb. 14/28	1929	4th	Silty clay loam	Red
7	23C Mauka	"	1919	July 15/27	1928	Sh. (4)	Silty clay loam	Red
8	23C Makai	"	1919	"	1928	Sh. (4)	Silty clay loam	Red
9	Ap. 2	May 15/28	1919	July 18/27	1928	Sh. (4)	Silty clay loam	Red
10	B	"	1925	Feb. 7/28	1929	1st	Silty clay loam	Red
11	C	"	1927	Feb. 1/28	1929	Plant	Silty clay loam	Greyish
12	6	"	1922	Mar. 17/27	1928	2nd	Silty clay loam (coral)	Greyish
13	15B	"	1921	Apr. 30/27	1928	3rd	Silty clay loam	Greyish
14	16A Pali	"	1922	Apr. 12/28	1929	Sh. (3)	Silty clay loam	Red
15	16A Below	"	1920	Apr. 14/28	1929	Sh. (4)	Silty clay loam	Red
16	16C	"	1920	Apr. 12/28	1929	Sh. (4)	Heavy clay	Blackish grey
17	19D	"	1919	Feb. 3/28	1929	5th	Silty clay loam	Red
18	19G	"	1919	Apr. 8/27*	1929	Sh. (6)	Clay loam	Greyish
19	24A	"	1928	May	1929	Sh. (6)	Silty clay loam	Greyish
20	26B	"	1916	Apr. 7/27*	1930	Plant being plowed	Silty clay loam	Red
21	10D	"	1924	June 15/27	1928	Sh. (6)	Clay	Black
22	13B	"	1921	Apr. 16/27	1928	1st	Clay loam (coral)	Red
23	13C	"	1918	Apr. 23/28	1929	Sh. (4)	Clay loam	Red
24	14C	"	1925	July 20/27	1928	5th	Silty clay loam	Red
25	21A	"	1923	Feb. 14/28	1929	1st	Silty clay loam	Red
26	22A Mauka	"	1918	July 14/27	1928	Sh. (2)	Silty clay loam	Red
27	22A Makai	"	1918	July 1/27	1928	Sh. (5)	Silty clay loam	Red
28	22B	"	1923	July "	1928	Sh. (5)	Silty clay loam	Brown
29	10B	"	1918	Feb. 21/28	1929	2nd	Clay loam	Red
		"		Aug. 8/27	1928	Sh. (6)	Heavy clay	Black

* Previous crop application finished.

In Fig. 5 the nitrifying power is plotted against the number of years since the fields were last plowed. It was thought that possibly the nitrifying power might be influenced by this factor, as it is characteristic of Hawaiian soils to lose in part their nitrifying power after the temporary stimulation which follows plowing (aeration). The time varies from as little as one month to twelve years, with no apparent existing relation. In Fig. 6 the nitrate content of the soil at time of sampling is plotted against the number of years since the field was last plowed, and this, too, shows little or no consistency.

In Fig. 7 an attempt is made to show graphically the relation between the time at which nitrogen was last applied to the field and the nitrate content of the soil at time of sampling. There are some data here of interest. The rapidity with which the nitrate disappears in soils 1, 16 and 22, and is retained or maintained by nitrification in 23, is of interest. The latter gives no response to nitrogen over 200 pounds, while one gave response to 250 pounds nitrogen.



DISCUSSION

It is not possible from these data on Ewa soils to estimate to what extent Arrhenius' observations under Java conditions will apply locally. While, as already stated, Burgess, about ten years ago, conducted a similar investigation on Hawaiian soils and reached the same conclusion, his classification of fertile and unfertile is general rather than specific. That is, his investigation was not conducted upon plots from nitrogen experiments, but rather from various areas in the Islands which were classified as to cane yields, and unquestionably all Ewa fields would have fallen in his classification as fertile. It is evident from Burgess' work that he had not reached the point where any specific recommendations could be made, but had, out of a selection of nine Island soils, found that the three poorest soils—one each from poor fields at Kukuihaele, Honomu and Kipahulu—had the lowest nitrifying power when using blood as a source of nitrogen (air-dried soils).

Relation of Time of Plowing to
Nitrate Content of Soil

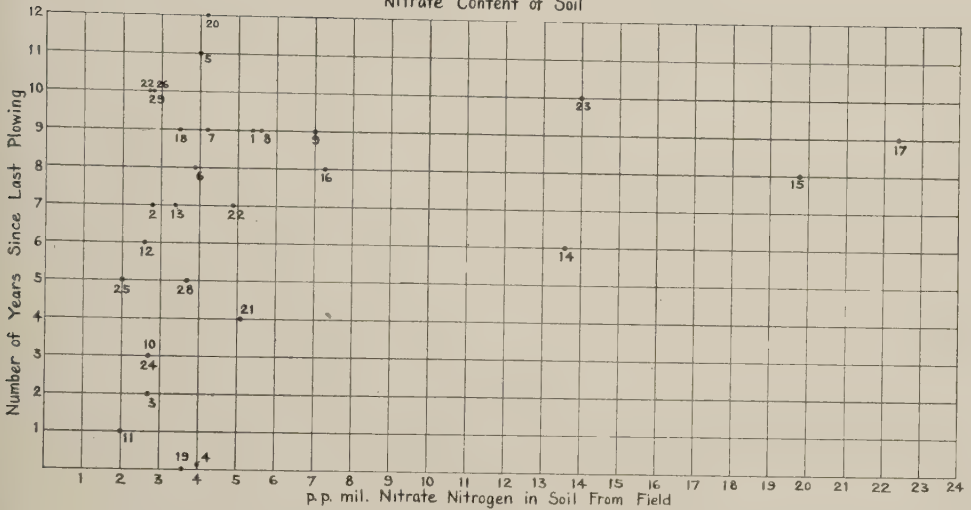


Fig. 6

Relation of Time of Fertilizer
Application to Nitrate Content of Soil

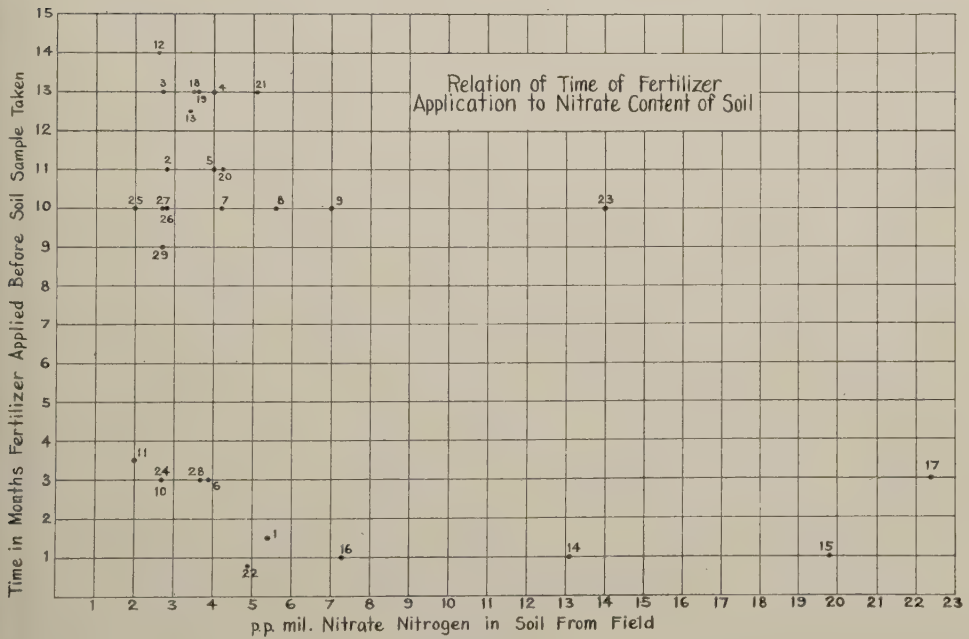


Fig. 7

It is to be regretted that Burgess' observations were not continued to include soil studies from harvested experiments. Then, too, he did not determine the nitrifying power for the soils' own nitrogen in lieu of added ammonium sulphate and blood; nor did he include the nitrifying power of the fresh soil along with the air-dried. It is upon the power of the soil to nitrify the nitrogen naturally present that the plant must depend during the period between fertilizer applications.

Much fundamentally valuable data upon our soil nitrogen were obtained by Kelley and Burgess during their investigations. It is of interest that Burgess found nitrogen-fixing bacteria well distributed in Island soils. Out of thirty soils taken from the four largest islands, all possessed the power of fixing nitrogen from the air. From these soils he isolated four different types of nitrogen-fixing bacteria, two of which he was not able to identify. The other two were *A. chroococcum* and *A. vinlandi*.

Their work has shown, on the whole, that Hawaiian soils are well supplied with nitrogen of high solubility as measured by acids and alkali, but difficult of nitrification. To quote Kelley: "It has been shown that nitrification does not take place in Hawaiian soils unless tillage is employed, and that the effects produced by aeration may soon be destroyed by continued wet weather. Virgin soils will not support nitrification until they have undergone aeration for several months, while cultivated soils sustain active nitrification."

On a comparative basis with mainland soils, the Ewa soils have a very low nitrifying power for their own soil nitrogen. This confirms what Kelley and Burgess have already shown to be true of Hawaiian soils. In other words, the nitrogen present in our soils is of low availability. Nitrifying bacteria appear to be universally present, as is shown by the ability of our soils to nitrify ammonium sulphate and other forms of added nitrogen. Of the 29 samples of soil examined, only 4 contained nitrogen as nitrate in amounts greater than 7.3 parts per million (dry soil), which would be approximately 20 pounds nitrate nitrogen per acre foot.

In Tables I and III, the next to the last columns show the per cent of soil nitrogen nitrified during incubation, an average of .44 per cent in the fresh soil and 1.6 per cent in the air-dried soil. Compare this with data published by Burgess on soils collected from all the states in the Union, showing an average for all of 14.6 per cent (maximum 50 per cent and minimum 1 per cent). There is this difference, however, which makes the comparison more striking, that where readily nitrifiable nitrogen was added to the mainland soils there did not always follow an increased nitrification such as was obtained in all the Ewa samples. In other words, poor nitrification in these mainland soils was due in most cases to absence of nitrifying bacteria, which we have not found to be true of Island soils.

Selecting from Arrhenius' observations two of the plantations which he cites, a comparison with Ewa soils is of interest. The soils of Krebet Plantation, which is located in a fertile area, and a low user of ammonium sulphate, showed a nitrifying power—16 soil samples—of 71 to 123 parts per million (Ewa soil 0-24 in the fresh condition and 9-45 after drying out in the air). The soils of Toelangan Plantation, which is the heaviest user of nitrogen fertilizer of all the Java plantations, showed a nitrifying power of 6-7 parts per million. On the basis, then, of

Java standards, we are forced to classify Ewa soils as requiring heavy nitrogen fertilization. The same would apply to practically all our Island soils.

Comparing the availability of nitrogen in Hawaiian and Java soils, the following is of interest: Seventeen samples of Java soils, which at time of sampling contained 1 to 21 parts per million nitrate nitrogen, increased on one month's incubation to 105 to 400 parts per million. Twenty-nine samples of Ewa soils, with nitrate nitrogen varying from 2 to 22 parts per million nitrate nitrogen at the time they were taken from the field, developed on one month's incubation 1.7—a loss—to 30 parts per million. It is evident from this that our Island soils should require much larger applications of nitrogen than Java soils.

The above comparisons indicate the difficulty to be met in making local interpretations on the basis of Java observations. On the other hand, in view of the correlations which have been noted in Java and those which Burgess had observed in our own plantation soils, such a line of investigations appears to warrant some attention as one phase of the field experiments on amounts to apply of nitrogen. In Java the heaviest application of nitrogen which is given to soils of little or no nitrifying power is 140 pounds nitrogen per acre (700 pounds ammonium sulphate). Their optimum or standard application, that which is applied to all soils, is 15 to 30 pounds nitrogen per acre. When we compare this with the minimum application of 150 pounds nitrogen it seems rather unfair to expect a correlation between nitrifying power and soil fertility in experiments in which the nitrogen is added at the rate of 150 to 300 pounds per acre. It seems fair to assume that within this range nitrogen is no longer a major growth limiting factor, and that any differences noted in yields of cane will be associated with some other condition.

Corn Root Rot Studies

The following excerpts are taken from "Corn Root Rot Studies," by B. B. Branstetter (Research Bulletin 113, University of Missouri, November, 1927). They indicate that the cause of root rot in corn is closely related to, or identical with, the cause of root rot in sugar cane:

"In 1918, when corn root rot first became recognized as a serious disease all over the corn belt, the most important manner of transmitting it was thought to be through planting seed corn infected with organisms, as *Diplodia zeae*, *Gibberella saubinetii*, *Fusarium moniliforme*, and others. . . .

"Other investigators found the organisms ordinarily present in seed corn to be responsible for seedling blights, but no direct evidence was given to show their capabilities of producing corn root rot. One type of root rot was found to occur generally when corn was grown on soils deficient in lime and available phosphate and potash. More recently, results from experiments carried on in Kentucky suggest that only seedling blight diseases result from the more common seed-borne

fungi, while true corn rot is produced by a different fungus organism that is not carried by the seed, but it is soil-borne. . . .

"Valleau has recently described corn root rot as a soil-borne disease produced by a *Pythium*-like organism that he was unable to isolate in pure culture. . . .

"Mention has already been made of an area in Block B of the Station field in which all the corn plants went down with badly rotted root systems in 1922. This suggested very plainly that if the corn root rot was caused by an organism it must be soil-borne in this case. Although no notes were taken on this infected area in 1921, the writer remembers with certainty that a large per cent of the plants were down in parts of the same area in 1921, when the preliminary seed treatment field experiment mentioned above was planted on this part of Block B. The spot in 1922 was located approximately in the center of the west end of Block B, a plot of ground about 130 feet square that has been handled differently from any other part of the whole field. . . .

"Previous to 1921 this plot had been seeded to sorghum in 1919 and in 1920, to corn in 1917 and 1918, and to wheat in 1916. . . .*

"The work of Hoffer and Carr, published in 1923, in which they stated that the most severe cases of root rots had been found in soils notable because of their deficiencies in lime and available phosphates, suggested to the writer to test the effects of lime and phosphate soil treatments on the appearance of corn root rot in the infected area in 1924. . . .

"The lime and phosphate were applied on the surface by hand, care being taken not to let the treatments overlap the adjoining plots. Immediately after application the material was raked in the top two or three inches of soil by hand. After a period of ten days the corn was planted by hand at the rate of two grains per hill on June 6, 1924. The soil was warm and the corn came up quickly and uniformly. From the first, the plants in the plots treated with phosphate were more vigorous, had a darker green color, and grew a little faster than the other plants. No differences were apparent in the plants of other plots.

"An observation made on July 26, just after the plants had begun to tassel, showed all plots in all parts of the field to be equally thrifty and growing well. The corn on the phosphated plots, however, still appeared more vigorous and a little larger than the remainder. Unfortunately, the writer changed his residence at this time and was not able to make further observations as the corn matured, the time at which the root rot had appeared in previous season. A member of the Experiment Station staff reported that by the first of October practically half of the plants were down in all the plots running through the infested area as mapped in 1923. No counts were made, but the report stated that there was no evidence of less root rot where the phosphate or lime, or both, had been applied. This evidence, though meager, indicates that root rot is due to some soil-borne organism, or to some soil condition other than the lack of available lime or phosphate, or both, in the soil. Also, the fact that plants from diseased seed and from clean seed went down

* The cane *Pythium* was found by C. W. Edgerton to attack sorghum, wheat, oats and corn, producing effects similar to those on cane. In *The Reference Book of the Sugar Industry of the World*, July, 1923, pp. 39, 40. (H. P. A.)

alike seemed to prove, in this case at least, that soil infection or a soil condition is a much more important factor than seed infection in producing corn root rot. . . .

"A number of greenhouse experiments were performed between growing seasons with different soils given various soil treatments. That results from greenhouse experiments can never be fully applied to field conditions was appreciated; nevertheless, it was believed that certain experiments with infected soil could be performed just as satisfactorily in the greenhouse. One great advantage of greenhouse experiments in this case was that corn plants could be grown to maturity during the period between growing seasons. Another advantage was the ability to control to a greater extent the environmental conditions under which the corn plants were grown. The object of these experiments was to secure some definite information on the organism or soil conditions causing corn root rot on the Missouri Experiment Station field. . . .

"These results quite convincingly indicated the presence in the infected soil of some causal agent producing corn root rot, and the absence of such a causal agent in the virgin or uncropped soil. . . .

"Without exception the plants grown in untreated soil had badly rotted root systems. Treatments with lime, manganese, and different amounts of sand had no deterrent effect on the development of corn root rot. Sterilization of the infected soil, however, did prevent roots growing in it from becoming diseased. This suggested that sterilization of the soil destroyed the causative agent producing root rot. And the fact that the plants growing in clean soil inoculated with *Diplodia zeae*, *Fusarium moniliforme*, and *Cephalosporium acremonium*, respectively, produced healthy root systems like those in the clean soil check plots strongly suggested that these organisms were not responsible for the diseased roots in the infected soil. . . .

"The root systems of the corn plants grown in 'clean' soil inoculated with *Diplodia*, *Gibberella*, and *Fusarium* showed no more root rot than the root systems of plants grown in uninoculated 'clean' soil, showing that the effect of these organisms was negligible compared with infected soil in causing corn root rot. Likewise, the unidentified species of *Fusarium* produced no rotting of the roots in the sterilized infected soil. But the plants growing in sterilized infected soil inoculated with 10 grams of diseased corn roots had badly rotted root systems, identical in appearance with those in infected soil. Neither of the sterilized soils inoculated with sterilized roots or planted with diseased seed produced plants showing any sign of root rot. This demonstrates the presence of the root rot organism, or agent if not an organism, in diseased corn roots; and further, that this organism or agent may be destroyed by sterilization. . . .

"The root systems of plants grown in infected soil treated with limestone, potash, and phosphate were slightly heavier and more extensively developed than the others, but they were just as badly rotted. This slight increase in growth in heavily fertilized infected soil is to be expected, inasmuch as Valleau and co-workers reported an increased root growth from fertilized infected soil compared with untreated infected soil. . . . The conclusion drawn was that the applica-

tion of neither potash, phosphate, nor limestone to the soil used reduced the amount of root rot in corn plants grown in it. . . .

"Corn root rot, as it occurs in Missouri, probably is caused by a *Pythium*-like organism similar to the fungus found by Carpenter to produce a root rot of sugar cane in Hawaii. The organism found by the writer in rotted corn roots is undoubtedly identical with the one Valleau and co-workers found invariably present in diseased corn roots in Kentucky. However, they were not able to isolate it in pure culture. Measurements of oospores of the organism growing in pure culture on corn roots in prune juice are the same as oospores of *Phytophthora cactorum*, and the two kinds of oospores look just alike. This suggests with practical certainty that Clinton saw oospores of this organism when he reported the occurrence of *Phytophthora cactorum* in corn stalks, the roots of which were severely infected with root rot. . . .

"From about 120 isolations from root tissue, four *Pythium*-like fungi were obtained in pure culture. Three of these proved to be identical, while the fourth one is apparently different only in that it produced oogonia and chlamydospores abundantly on potato dextrose agar. . . .

"Little opportunity has been afforded to study the taxonomy of the organism in order to determine definitely its identity. In a pure culture growing on corn roots in prune juice, mycelium, oogonia, and oospores are produced abundantly and chlamydospores less abundantly. The hyphae are non-septate and vary considerably in diameter, due to peculiar swellings occurring at intervals. Ordinary hyphae are 2 to 4 microns in diameter, while the swollen places vary in diameter up to 20 microns. Oogonia are spherical, averaging 30 to 32 microns in diameter. Oospores average 28 to 30 microns in diameter and almost completely fill the oogonial activity. The type of antheridium shown suggests that this organism belongs to the genus *Pythium*. No zoosporangia nor zoospores have been observed. It is practically certain, however, that the organism is not *Phytophthora cactorum*, a species of a closely related genus. . . .

"No conclusive inoculation trials have been carried out to prove the pathogenicity of the *Pythium*-like organism in producing typical corn root rot. Results of preliminary inoculation trials, however, are very suggestive. . . .

"From the results of investigations reported in this paper—showing that reductions in yield from planting heavily infected seed corn are due to seedling blight and not to root rot; that root rot does not develop in corn plants grown in uninfected soil inoculated with either of the four most common seed-borne organisms; that corn root rot does develop in plants grown in uninfected soil inoculated with diseased corn root containing spores and mycelium of a *Pythium*-like fungus; and that this *Pythium*-like organism may be easily re-isolated from young corn plants after being inoculated and becoming infected with a pure culture of the fungus—it is believed that corn root rot in Missouri is caused by a *Pythium*-like fungus similar to the one found by Carpenter to be the cause of root rot of sugar cane in Hawaii. . . .

"Corn root rot does not occur when disease-free corn seedlings are grown in virgin soil, nor in infected soil if sterilized.

"Uninfected soil inoculated with *Diplodia zeae*, *Gibberella saubineti*, *Fusarium moniliforme*, and *Cephalosporium acremonium* produces a certain amount of seedling blight, under greenhouse conditions, but no root rot in the plants that survive. . . .

"Disease-free seedlings grown in sterilized infected soil inoculated with corn roots diseased with root rot develop into average sized plants in the greenhouse, but have badly rotted root systems typical of roots diseased with corn root rot. . . .

"A *Pythium*-like fungus was isolated from diseased corn roots growing in infected soil. The roots of young corn plants were successfully inoculated with this organism, which was re-isolated in pure culture from the inoculated roots. . . .

"Corn planted and inoculated with the *Pythium*-like organism in the field at different dates during the spring of 1927 developed typical corn root rot symptoms from the first planting, made April 16, but not from later plantings. It is suggested that the unusually low temperature of 5.6 degrees below normal during August may have been a factor in preventing development of root rot in the later corn. . . .

"Corn root rot in Missouri is probably caused by a soil-borne *Pythium*-like fungus."

(H. P. A.)

Notes on *Pythium* Root Rot

IV

By C. W. CARPENTER

In the third article of this series of notes on current investigations of root rot, a working theory was outlined for further studies of the parasitic relation of *Pythium aphanidermatum* to cane roots. In the present paper is presented some experimental evidence, recently obtained, which indicates that in the theory adopted we have a field of research pertinent to the fundamental etiology of the disease.

Essentially the theory expressed was that excess or unbalanced nutrients lead to susceptibility of the roots to attack by this fungus. The nitrogenous group of nutrients was thought most likely to be in excess, or unbalanced by available potash and phosphoric acid, and was chosen for first consideration. It appeared reasonable from the history of root disease that the resistance of such varieties as H 109, Yellow Caledonia and Demerara 1135, as well as the susceptibility of the Lahaina, H 146 and E. K. 28 varieties, was associated with varietal idiosyncrasies of nutrition.

The theory of unbalanced nutrition was devised as a working hypothesis to probe the nature of some factors, the existence of which had long been suspected, and which appeared to greatly influence the course of the root disease. Since there are records of remarkable recoveries of Lahaina following unusual rainfall, and

since this variety continues to grow well in certain localities where the fungus is known to be present, we are forced to consider that the variety has not deteriorated seriously, but that the growing conditions for this particular variety in the presence of the fungus have become unsuitable over large areas. If heavy rainfall improved conditions when sufficient moisture for growth had been maintained, some soluble material might have been leached out or a suitable balance of nutrients restored. Thus, it was theoretically presumed that the root disease of Lahaina was not due to a shortage of any nutrient, but rather to an improper balance of nutrients, or the presence of some soluble material which induces susceptibility. In the light of some experiments with cane compost discussed below, it is probable that this soluble agent, if not nitrates, is at least present as a disintegration product of cane crop residues and is possibly peculiar thereto. It might accumulate in harmful amounts when the decomposition of cane trash, stubble and roots is accelerated with artificial fertilizers. Rapid disintegration occurring in the soil under our climatic conditions, with minimum moisture, simulates the process of composting with "Adco," in the compost heap.

Some thirty preliminary experiments, rather sketchy in nature, with water cultures and small soil cultures with Lahaina cane and H 109, were conducted in the past few months, to obtain an inkling of the truth or fallacy of the working theory. These experiments were not expected to demonstrate any particular fact, but were merely a preliminary probing for qualitative evidence concerning induced susceptibility. From them, considering the common tendency of isolated observations, we are justified, however, in drawing some inferences as to the general trend of the evidence. Supported by this trend, definite evidence that the working theory is essentially sound as a useful hypothesis in our studies was found in three experiments, "A," "B," and "W," cited below.

EXPERIMENTS

Experiment "A."—Lahaina cane was grown in root-study boxes in thoroughly mixed soil from the Makiki fields. The root-study boxes, with glass sides, have a soil surface area of about one-third of a square foot; they are 12 inches by 4 inches by 16 inches deep, inside measurements.

Both Lahaina and E. K. 28 have grown well in the Makiki Station fields. There is no history of serious root rot of Lahaina in this location, the disease being either absent, or at least not a subject of comment. E. K. 28 grew well here, though an utter failure from *Pythium* root rot at the Alexander Street plots (cf. Experiment "B"). This Makiki field soil has but a minimum reserve of nitrogenous material, judging by the appearance of the leaves of H 109 grown therein in small cultures, the plants becoming pale green after a few weeks growth. It has the reputation of containing reserves of potash unusual for local soils.

The seed used was top cuttings of healthy Lahaina from the Mid-Pacific fields, Manoa.

After a growing period of four months and twenty-one days, no striking evidence of disease having been noted in the top growth, or in the roots visible through

the windows of the boxes, the root systems were washed out July 25th. Leaf growth had been pale except in those plants receiving applications of nitrogen.

No root rot was found either in the controls or in those to which ammonium sulphate had been applied in what was considered excessive amounts.

Fig. 1 shows the root systems of representative plants. Nos. 3 and 4 were controls and received no fertilizer. Nos. 6 and 12 received 30 cc. of 40 per cent ammonium sulphate (c.p.) in three applications of 10 cc. each, May 6th, 19th and 29th. Nos. 17 and 23 received 2 grams of sodium nitrate (c.p.) before planting, and 30 cc. of 40 per cent ammonium sulphate the same date as No. 12.

Root rot occurred in but one box of this series of twenty-four units. To this box, which had received a total of 6 grams of sodium nitrate (c.p.) without apparent effect in inducing root rot, a mulch one inch deep of well-rotted cane trash (composted with "Adco") was applied three weeks before the conclusion of the experiment. A flush of new roots about 6 inches long were all flaccid when the plant was washed out. Roots, new and white, but somewhat older, being about 10 inches long, were unaffected, as was the mass of older roots. Apparently, then, only those roots in the upper few inches of soil which were very young, or started to grow out stimulated by the leaching from the compost percolating downward, were attacked by the *Pythium* root rot. Those roots, the tips of which had passed below the zone of influence of the compost extract, entirely escaped injury, and the fungus did not attack the proximal portions of such roots, though they were in the immediate vicinity of the flaccid roots. This observation of root rot occurring in the presence of cane compost confirmed the results obtained earlier in Experiment "W", discussed below.

Experiment "B."—Seed of the same lot of Lahaina was used as in Experiment "A", twenty-four root-study boxes were filled with thoroughly mixed soil taken from the immediate vicinity of good Lahaina stools at the Alexander Street cane plot. This soil has never been fertilized with artificial fertilizers, but cropped with cane for many years. Lahaina has grown moderately well, with no definite root rot history. However, E. K. 28 failed miserably near by, in an area in which some years earlier a very large amount of cane trash had been incorporated. The E. K. 28 was fertilized twice with ammonium sulphate, but previously the area had not been fertilized, except, possibly, in very recent crops. Lahaina is growing fairly well in this area, following the poor growth of E. K. 28.

The Lahaina grew well in the root boxes, with better leaf color than in the Makiki soil (Experiment "A"). Plants receiving heavy applications of sodium nitrate were stunted, but of deeper green color than the unfertilized controls.

When washed out, July 31st, at the age of four months and fifteen days, those plants which had received an excess of sodium nitrate were badly affected with *Pythium* root rot. The typical fungus was present, even in the boxes where it had not been introduced. Apparently the fungus was naturally present, suitable conditions causing susceptibility. Moderate root rot occurred in those which had received ammonium sulphate in rather large amounts.

Since the experiment was not complete with sufficient units to furnish reliable data on amounts of nutrients harmful, or to contrast the relative effect of sodium

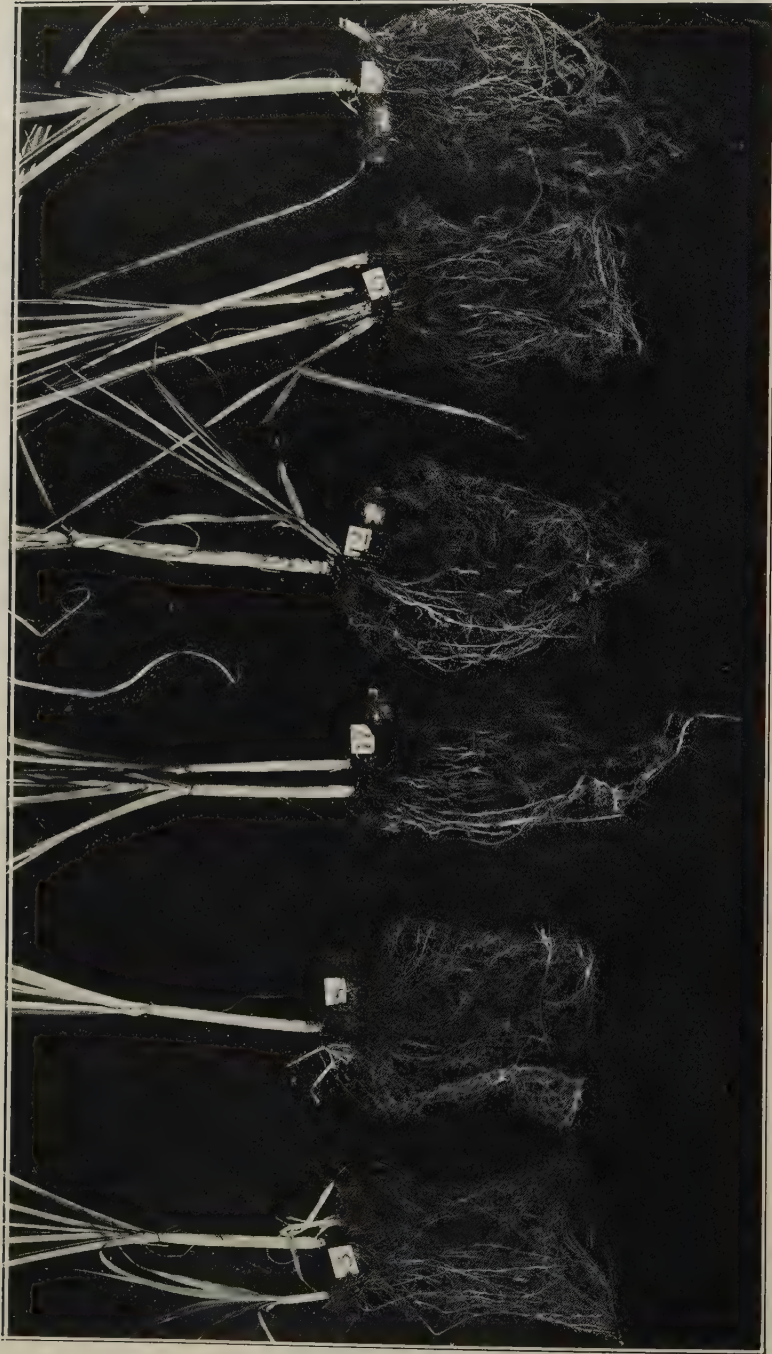


Fig. 1. Root systems of Lahaina cane in Makiki soil, with and without heavy applications of ammonium sulphate. No root rot resulted (Experiment A).

Nos. 3 and 4, controls; Nos. 6 and 12, ammonium sulphate 12 grams; Nos. 17 and 23, 2 grams sodium nitrate before planting; otherwise same treatment as Nos. 6 and 12.



Fig. 2. Root systems of Lahaina cane plants of Experiment B, with and without heavy applications of sodium nitrate. Serious root rot in Nos. 6 and 18. Nos. 4 and 7, controls; No. 5, potassium sulphate 2.0 grams; No. 6, sodium nitrate 15 grams; No. 15, ammonium sulphate 2.4 grams; No. 16, ammonium sulphate 4.8 grams and potassium sulphate 2.0 grams; No. 18, ammonium sulphate 3.2 grams and sodium nitrate 10.0 grams. From left to right the numbers are: 4, 5, 6, 7, 15, 16, 18.

nitrate and ammonium sulphate, details of this phase are not available from our preliminary work. However, where a little ammonium sulphate was used, root rot was absent or negligible; where the amount of nitrogen added as sodium nitrate could be considered as excessive for one plant in such a limited amount of soil, root rot was serious. For example, referring to Fig. 2, the controls, Nos. 4 and 7, received no nutrients; No. 5, potassium sulphate (c.p.) 2.0 grams; No. 6 received 30 cc. of 50 per cent solution of sodium nitrate (c.p.) in three doses of 10 cc. each, on May 6th, 19th and 29th; No. 15 received 2.4 grams ammonium sulphate; No. 16, 4.8 grams ammonium sulphate, 2 grams potassium sulphate; No. 18 received 8 cc. of 40 per cent ammonium sulphate in two doses of 4 cc., on March 12th and April 3rd, and 10 grams of sodium nitrate on June 2nd. *Pythium aphanidermatum* was introduced into the soil of No. 7 on April 9th, 1928. Further tests of this type would be necessary to estimate the possible influence of excess sodium ions.

Experiment "M."—An experiment is being conducted with the variety H 109 in Waipio soil in an attempt to induce root rot with excessive applications of sodium nitrate and ammonium sulphate. It was thought that if exact conditions suitable for the development of root rot in this variety could be learned, we would have a better understanding of the sporadic cases of *Pythium* type root rot which occur, particularly in dry years, or periods of other adverse weather conditions, with this variety and others of our standard canes. Several representative boxes were washed out.

No serious root rot has yet resulted in this experiment. Some typical root rot has appeared in boxes receiving heavy applications of ammonium sulphate, followed very recently by a surface mulch of cane compost. Conversely, then, this evidence with the root-rot-resistant H 109, in connection with the rot resulting in Lahaina in some soils treated with excess nitrates, supports the general theory that varietal resistance is correlated with peculiar nutritional properties. It may be noted that in some of the first experiments (1918), H 109, D 1135 and Yellow Caledonia were grown in a potting soil rich in organic matter. It was then recorded that root rot occurred in some degree and that apparently resistance was merely a relative quality.

Fig. 3 shows: Controls Nos. 1 and 3. No. 7 received 2 cc. of a 50 per cent solution of sodium nitrate (c.p.) when planted and 25 grams of sodium nitrate fertilizer in one large dose, June 1st; No. 18 received a total of 63 cc. of 50 per cent solution of sodium nitrate in several smaller doses; No. 25 received a total of 6.5 cc. of 50 per cent sodium nitrate solution and 45 cc. of 40 per cent ammonium sulphate, besides 32 grams of calcium hydroxide (c.p.) to facilitate nitrification. Burning of leaf margins of the lower leaves and checked growth were the only marked effects of these large applications on H 109.

Construing this evidence obtained from growth of H 109 in a soil sick for Lahaina, with the fact that H 109 is susceptible to *Pythium* root rot in some degree, we have added evidence here that nitrates act indirectly rather than directly in inducing susceptibility. Experiments are now under way with H 109 in soils

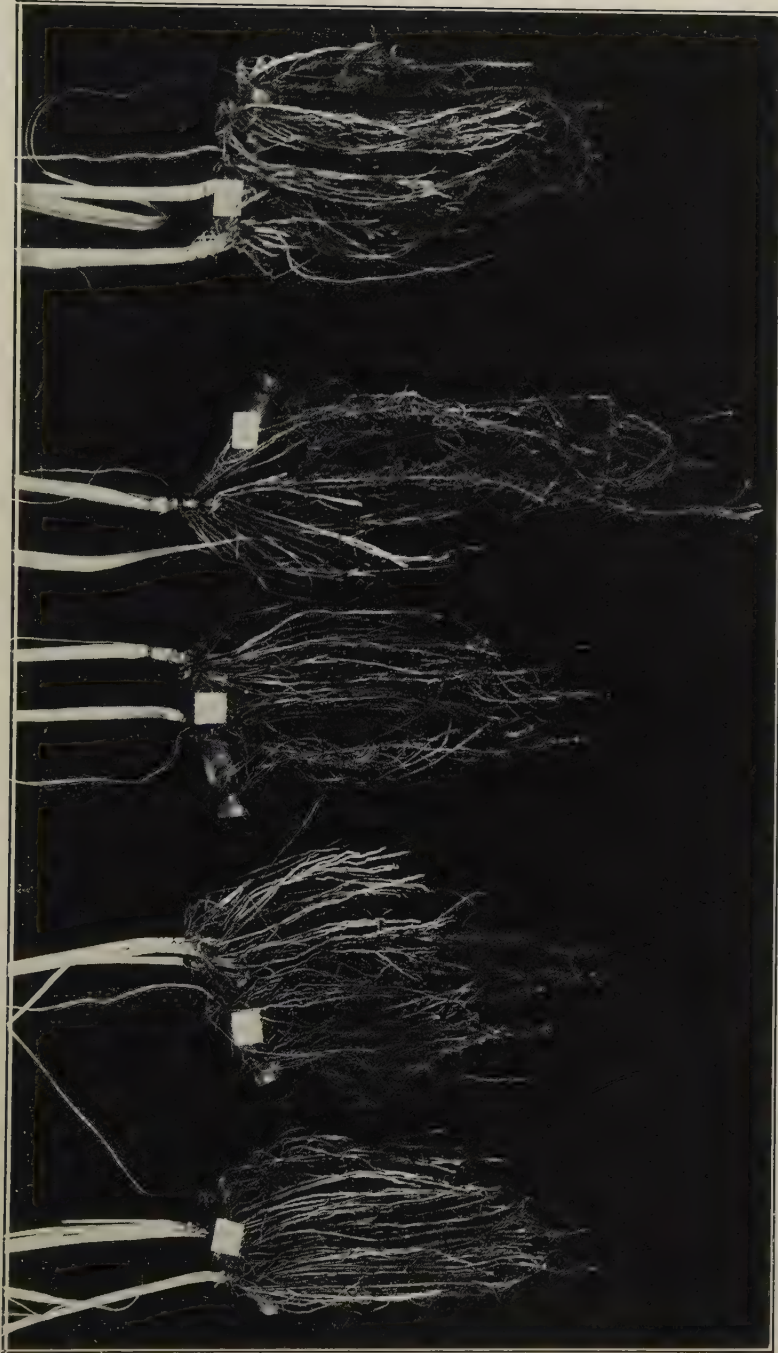


Fig. 3. Representative root system of plants of Experiment M. H 109 cane in Waipio soil.
 Nos. 3 and 1, controls; No. 7, sodium nitrate 26 grams; No. 18, sodium nitrate 31.5 grams; No. 25, sodium nitrate 4.5 grams,
 ammonium sulphate 18.0 grams, calcium hydroxide 32.0 grams.
 From left to right the numbers are: 3, 1, 7, 18, 25.

with compost amendments to which nitrates will likewise be added, in further attempts to overcome the resistance.

Experiment "W."—For a small experiment, virgin soil from an excavation in Pawaa, South King Street, was used. The control root boxes contained only virgin soil. One series contained virgin soil 75 per cent by volume and well rotted compost (cane trash composted with "Adco") 25 per cent. Another series contained virgin soil 50 per cent and compost 50 per cent. All were planted with Lahaina top cuttings from a large stool of healthy Lahaina growing at the Alexander Street field. No nutrients were added to any.

Growth was fair in the controls. Slightly longer leaves in the mixture of 25 per cent compost were noticed. The plants in the 50 per cent compost mixture were distinctly stunted, and some shoots died after a few weeks.

The roots of a few units were washed out July 5th after a growing period of three months, with the following results:

Virgin soil: The root system was normal and extensive with insignificant signs of root disease. After careful search the organism was found to be present, though not intentionally introduced, demonstrating that absence of root rot was not due to absence of the proper organism. (Figs. 4 and 5.)

Virgin soil plus 25 per cent compost: The plants appeared slightly stimulated in leaf growth compared with the controls. The root system was badly affected with *Pythium* root rot, including the young primaries from the shoot nodes. Active root rot was continuing. (Figs. 4 and 6.)

Virgin soil plus 50 per cent compost: The plants were decidedly stunted, apparently being just able to keep alive. Scarcely any roots were present. Those remaining were badly rotted and full of typical *Pythium* mycelium and oospores. This represents the final stage in root rot with complete root destruction (Fig. 4).

That less than 25 per cent of compost is effective in inducing a high degree of susceptibility in Lahaina roots is indicated by the observation noted in Experiment "A", where a surface mulch of compost brought on a bad attack. It may be noted that the agricultural department customarily uses 40 per cent of this same compost in soil for seedling propagation, so that 25 per cent compost cannot be considered an unusually extreme soil amendment. To this material the Lahaina variety appears to be very sensitive.

Fig. 4 shows the root systems of some of these plants. No. 1, control in virgin soil; No. 2, virgin soil with 25 per cent compost; No. 3, virgin soil with 50 per cent compost. Fig. 5 shows a close view of the root system of the control, and Fig. 6 of the roots in 25 per cent compost. Close inspection of the latter will reveal the rotted condition, and that the large primary roots are merely ragged remnants and empty skins.

DISCUSSION

The preliminary results with Lahaina cane grown in mixtures of virgin soil with cane compost and in cane soil fertilized with an excess of sodium nitrate



Fig. 4. Root systems of plants of Experiment W, Lahaina cane, virgin soil with compost amendment. (No nutrients added to any.)

1. Virgin soil. 2. Virgin soil, 75 per cent, and cane compost 25 per cent by volume; serious root rot. 3. Virgin soil, 50 per cent, and cane compost 50 per cent; complete destruction of roots, and death of shoots.



Fig. 5. Larger view of No. 1, control, shown in Fig. 4.



Fig. 6. Larger view of No. 2, roots in 25 per cent compost mixture with virgin soil, shown in Fig. 4. Majority of roots were flaccid, scarcely holding together for photographing.

exemplify novel features of our studies. With respect to the effect of sodium nitrate in inducing root rot in the soil from the Pathology Plot (Experiment "B") and the failure of ammonium sulphate to produce similar effect in the Makiki Station soil (Experiment "A"), our data are very meager, and few features of the two experiments are comparable. The fact that excess nitrate is in some way related to the disease is significant, and that perhaps is all that we are justified in inferring from Experiments "A" and "B". Conversely, in Experiment "M", the resistance of H 109 to the disease, maintained in a sick soil in the presence of excessive applications of ammonium sulphate and sodium nitrate, but weakening in the presence of compost leachings, appears significant from the viewpoint of varietal differences. From this experiment we obtain the hint that differences in susceptibility are correlated with nutritional or absorptive differences.

From the striking effect produced on Lahaina cane roots grown in mixtures of compost and virgin soil we are justified in inferring that the active factor in induced susceptibility is a product of the decay of cane residues (Experiment "W").

This effect of compost may be solely from the nitrogenous material it contains. That the nitrogenous fertilizers have a role in root rot we inferred from Experiments "B" and "M". It seems probable, however, that the role of inorganic nitrogenous nutrients in the soil is an indirect one, as mentioned above. Trash decomposition in the soil with minimum moisture and in the presence of fertilizers, simulates composting with "Adco." In this rapid decomposition of trash, high in cellulose, available nitrogen would be the limiting factor for the bacteria concerned. The active factor in induced susceptibility may be a product of this accelerated decay of cane trash and other organic matter facilitated by nitrates rather than a direct effect of excess nitrates or lack of nutrient balance. Unusual rainfall, which has been reported as the only unusual precedent condition to crop recoveries over large areas, would not only dilute or leach out a portion of the harmful product, but by removing soluble nitrates would check further elaboration of the substance by the bacteria.

Unless nitrates, or other inorganic nitrogenous compounds, prove to be the active factors, a consideration of possible organic nutrients appears necessary, and of that elusive quality of organic manures which profoundly affects plant growth, a quality apparently extraneous to the content of the three major nutrients. We are led, from the evidence obtained by our diffuse preliminary experimenting, to conjecture specifically on the relation of crop residues to subsequent crops of the same kind from the aspect of increased susceptibility to disease. Experiments will be continued with cane compost and other organic matter in relation to susceptibility to *Pythium* and the effect of sodium nitrate, ammonium sulphate, etc., as accelerators of trash decomposition in the soil, as well as the effect of unbalanced nutrients.

It would be interesting to know the effect of crop residues on corn root rot disease and other diseases associated with which a *Pythium*, identical with our

cane fungus or closely resembling it, has been reported.* We have some evidence that the roots of a top seed piece of Lahaina from a "healthy" soil, germinated in water, cannot be readily entered by *Pythium*; but that roots of a similar top seed piece from a plant grown in sick soil, germinated in water, are entered in a few hours. If a crop is sensitive to products of previous growth of the same crop in a soil, accelerated decomposition of such crop residues in the presence of the new crop might be expected to accentuate the harmful effects. Such acceleration of decay of residues may occur after the crop is fertilized, the various tissues of the latter, grown in the presence of the product and modified thereby, possibly becoming easy prey to more or less specific parasitic organisms.

The conditions which would be expected to foster the "composting" of cane residues in the soil—hot, dry weather and plentiful supply of nitrogen—would also tend to increase absorption as a result of increased transpiration.

Visualize the cane plant in this condition of increased susceptibility to root rot, increased absorption and transpiration, suddenly losing the major portion of the root system. We would expect to have the following effects:

(1) Positive symptoms of failure to absorb; lack of water and starvation effects: yellowing, premature drying and sloughing of lower leaves; tapering, short joints of stick, and, with susceptibility maintained, ultimate death of the stool. Few, if any roots present, and those close to the surface, since they could not, if susceptible, persist long enough to reach downward any distance.

(2) Accompanying or negative symptoms of checked growth and of failure to use nutrients or to eliminate waste products of metabolism: Abnormal accumulations in various parts of the plant of unnecessary materials, such as waste products, aluminum, iron, etc.

(3) Attack of weak parasites and saprophytes. Top rot, rind disease, red rot, etc.

Such are the chief symptoms of cane root disease as recorded by various investigators—positive symptoms of poor absorption and assimilation, and, more recently, emphasis on the negative symptoms of disturbed metabolism, accumulations, etc.

It is inferred from the evidence and hints thus far obtained in experiments on cane root diseases that we have the following effective factors in the etiology:

* Edson, H. A. *Rheosporangium aphanidermatus*, a new genus and species of fungus parasitic on sugar beets and radishes. In *Journal Agricultural Research*, vol. IV, No. 4, 1915, pages 279-291. See also vol. IV, No. 2, pages 161-163.

Subramaniam, L. S. A *Pythium* disease of ginger, tobacco and papaya. In *Mem. Department Agriculture India*, vol. X, No. 4, pages 181-194, 1919.

Carpenter, C. W. Preliminary report on root rot in Hawaii, Hawaii Agricultural Experiment Station, Press Bul. No. 54, 1919. *Pythium* in relation to Lahaina Disease and Pineapple Wilt. *Hawaiian Planters' Record*, vol. XXIII, No. 3, 1920.

Drechsler, Charles. The cottony leak of cucumbers, caused by *Pythium aphanidermatum*. *Journal Agricultural Research*, vol. XXX, No. 11, 1925.

Harter, L. L., and Whitney, W. A. A transit disease of snap beans, caused by *Pythium aphanidermatum*. *Journal Agricultural Research*, vol. XXXIV, No. 5, pages 443-447, 1927.

Valleau, W. D., Karraker, P. E., and Johnson, E. M. Corn root rot, a soil-borne disease. *Journal Agricultural Research*, vol. XXXIII, No. 5, pages 453-476, 1926.

Branstetter, B. B. Corn root rot studies. University of Missouri, Agricultural Experiment Station, Res. Bul. 113, 1927.

(1) Predisposition of cane varieties in diverse degree, associated with (2) nutritional or absorptive idiosyncrasies (3) which lead to susceptibility of certain varieties to (4) *Pythium aphanidermatum*. Experiments have repeatedly demonstrated that with a susceptible variety no root rot disease results if the sick soil be sterilized, but introduction of *Pythium aphanidermatum* results in root rot. Since the fungus was harmless in virgin soil, but was destructive in virgin soil plus cane compost, the existence of factors inducing susceptibility is obvious. From other evidence in our experiments, it does not appear probable that these are physical in nature.

SUMMARY

Evidence was obtained that susceptibility of Lahaina to root disease is acquired, and is a condition resulting from absorption of soluble substances. The latter are present in cane compost.

Sodium nitrate in excess, directly or indirectly in association with cane residues in the soil, induced susceptibility to *Pythium* root rot in Lahaina cane.

Cane compost (trash composted with "Adco") in moderate amounts in virgin soil was accompanied by a high degree of susceptibility. A mere trace of root rot was found in the virgin soil alone and the fungus was found to be present. Greater amounts of compost content resulted in total destruction of roots and death of shoots. No nitrogen or other material, except tap water, was added.

Disintegration and decomposition of cane trash, stubble and roots in the soil in hot weather, with minimum moisture, in the presence of artificial fertilizers, simulate composting with "Adco." The bacteria decomposing cellulose respond to fertilizers under proper temperature and moisture conditions. Accelerated decomposition of crop residues and organic matter in the presence of a crop might be expected to release harmful products, or tend to possible excesses of beneficial and stimulative inorganic or organic nutrients.

Under our theory of acquired susceptibility, the etiology of cane root rot in which *Pythium aphanidermatum* is the active agent, is inferred to be substantially as follows:

(1) Predisposition of cane varieties in diverse degree, associated with (2) nutritional or absorptive idiosyncrasies, such as sensitiveness to organic residues, leading in certain varieties to (3) susceptibility to (4) *Pythium aphanidermatum*.

Tests of Varying Amounts of Nitrogen and Potash in Relation to Eye Spot During the 1927-1928 Eye Spot Season

BY J. P. MARTIN

In every test heretofore, heavy applications of nitrogen when applied late in the season have consistently increased the severity of the eye spot disease on H 109 cane, as determined by eye spot counts taken at two-week intervals during the eye spot season. These previous experiments consisted of five to seven repetitions of each treatment with plots averaging ten to twelve 35-foot lines. The tests were not harvested, thus making it impossible to determine the difference in sugar yields from the various treatments.

The experiments as presented in this article were planned by C. H. Butchart, of the Waialua Agricultural Company, Limited, H. K. Stender, of the Experiment Station, and the writer, April, 1927. The objects of these experiments were:

1. To determine by eye spot counts and growth measurements the effect of eye spot on H 109 cane receiving varying amounts of nitrogen and potash late in the season.

2. To determine the sugar yields at harvest from the plots receiving varying amounts of nitrogen and potash when applied late in the season.

It was possible to use the same experiment for eye spot as well as agricultural studies. R. E. Doty, of the Experiment Station, put the two experiments in and the writer conducted all eye spot counts and growth measurements. The areas selected for these experiments were in fields that have always been badly affected with eye spot at the Waialua Agricultural Company.

The test with varying amounts of nitrogen in relation to eye spot was located in Field Gay 1, and consisted of six repetitions of each treatment with watercourse plots averaging 0.29 of an acre each. The cane in this field was H 109 first ratoons, and the previous crop was harvested July 25-30, 1927. The nitrogen treatments to the various plots were as follows:

Plots	August, 1927 First Season			April, 1928 Second Season			Total		
	N	K ₂ O	P ₂ O ₅	N	K ₂ O	P ₂ O ₅	N	K ₂ O	P ₂ O ₅
6 A.....	30	35	35	100	...	...	130	35	35
6 B.....	50	35	35	100	...	...	150	35	35
6 C.....	70	35	35	100	...	...	170	35	35
6 D.....	90	35	35	100	...	...	190	35	35

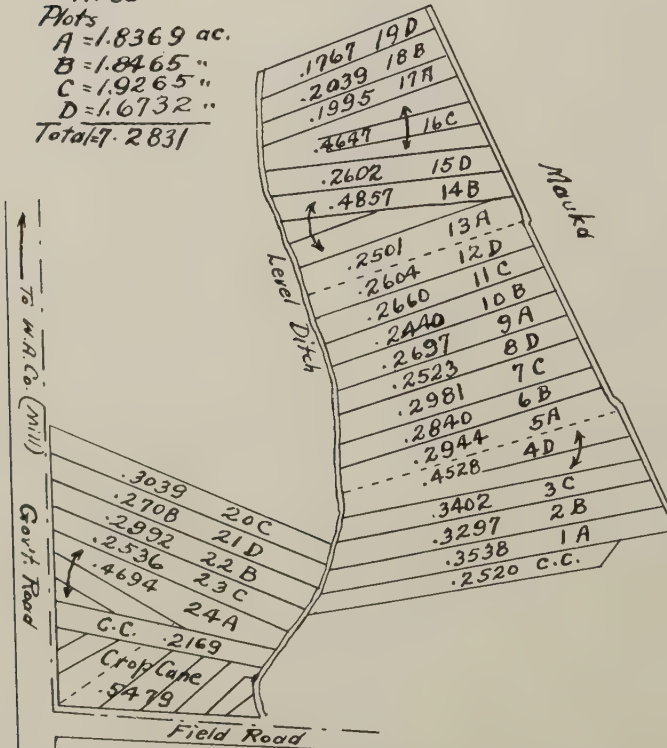
According to the soil analysis by the chemistry department, this field contained high amounts of both potash and phosphates.

Waialua Agri. Co., Exp. 18, 1929 Crop.

Field Gay I

Fertilizer Exp. Amount of Nitrogen to apply.
Cane - H109 1st Ratoons.
Previous Crop Harvested July 25-30, 1927
24-Plots of irregular size.

Area
Plots
A = 1.8369 ac.
B = 1.8465 "
C = 1.9265 "
D = 1.6732 "
Total = 7.2831



Fertilization lbs. p.a.

Plots	No. of Plots	1 st Season 8-27			2 nd Sea.			Total		
		N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
A	6	30	35	35	100	130	35	35	35	35
B	6	30	35	35	100	150	35	35	35	35
C	6	70	35	35	100	170	35	35	35	35
D	6	30	35	35	100	190	35	35	35	35

N₂ from Ammonium Sulphate
Amm. Sulphate = 20.5% N₂
Sul. of Potash = 50% K₂O
Super Phosphate = 21% P₂O₅

Fig. 1

VARYING AMOUNTS OF NITROGEN IN RELATION TO EYE SPOT

Field Gay, M.A. Co. Ltd.

	August 1927			April 1928			Total		
	1st Season			2nd Season					
	N ₂	P ₂ O ₅	K ₂ O	N ₂	P ₂ O ₅	K ₂ O	N ₂	P ₂ O ₅	K ₂ O
6 A Plots	30	35	35	100	130	35	35		
6 B "	50	35	35	100	150	35	35		
6 C "	70	35	35	100	170	35	35		
6 D "	90	35	35	100	190	35	35		

Ten growth measurements were taken from each plot or 60 growth measurements per treatment every two weeks. The vertical lines represent the average growth per stalk per treatment every two weeks. The accumulative growth curves indicate the total average growth per stalk per treatment. The total number of eye spot lesions were counted every two weeks from 220 leaves per plot or a total of 120 leaves per treatment. The counts were taken on the first fully unfolded leaf on the same marked stalks throughout the experiment. The eye spot curves below represent the average number of lesions per leaf per treatment. All nitrogen applied was from ammonium sulphate.

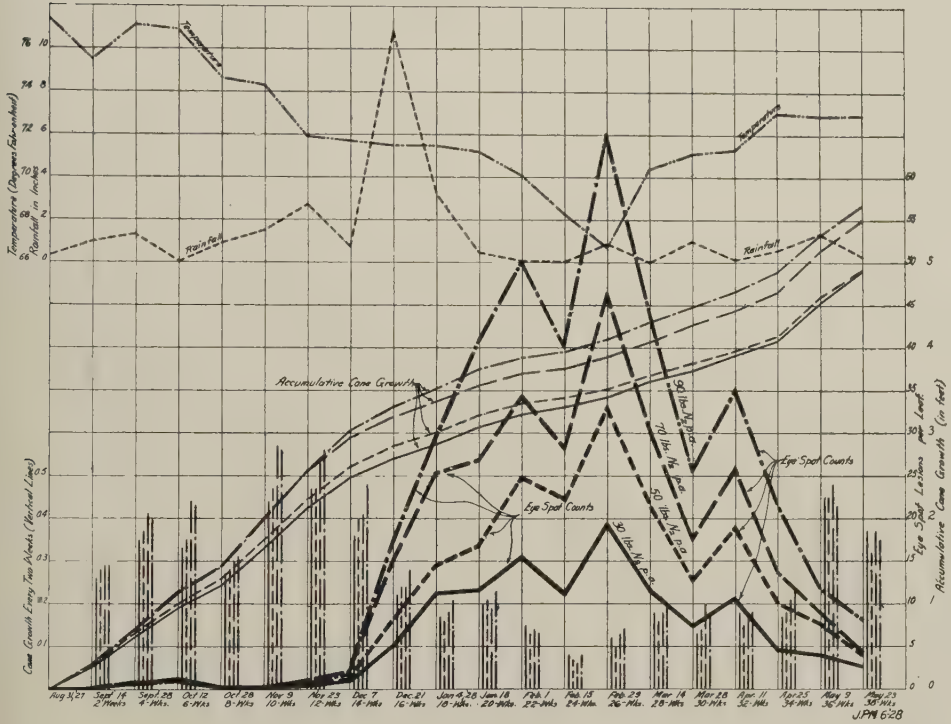


Fig. 2

All nitrogen was applied from ammonium sulphate, and a detailed plan of the experiment is given in Fig. 1. The nitrogen was applied August, 1927, during the first season, and April, 1928, during the second season.

Ten growth measurements were taken every two weeks from each plot, and the average growth per stalk per treatment is shown in Fig. 2 by the vertical lines; the accumulative cane growth is also illustrated in Fig. 2 by the curves labeled "Accumulative Cane Growth." With an increase in nitrogen there is a corresponding increase in cane growth, as brought out by the growth curves. There was only a small difference between the A and B plots, and likewise in the C and D plots. The greatest difference of cane growth occurred between the A and B plots as compared to the C and D plots. In other words, the growth response from 30 pounds of nitrogen was about the same as from 50 pounds of nitrogen per acre, and there was only .20 of a foot difference between the plots receiving 70 and 90 pounds of nitrogen per acre.

All plots received a uniform amount of nitrogen during the second season in order to determine by harvesting results the following point: Where nitrogen is reduced during the first season to control eye spot, is it necessary to make up the difference during the second season? This will be determined when the experiment is harvested in 1929.

The number of eye spot lesions on twenty leaves from each plot were counted every two weeks, and the average number of lesions per leaf per treatment is presented in Fig. 2 by the heavy curves labeled "Eye Spot Counts." It is apparent that the eye spot counts increased with the added amounts of nitrogen applied. The average number of infections or eye spot lesions per leaf from each treatment on February 29, 1928, the peak of the season, was as follows:

		Eye spot lesions per leaf
		February 29, 1928
A	Plots—30 lbs. N per acre.....	19.58
B	" " —50 " " " "	33.37
C	" " —70 " " " "	46.50
D	" " —90 " " " "	65.11

On February 29, 1928, the D plots showed 332 per cent, the C plots 237 per cent, and the B plots 170.4 per cent more eye spot lesions per leaf than the A plots. The reduction of eye spot by decreasing the nitrogen applications to those areas subject to the disease is quite conclusive, and it will be necessary to secure the harvesting results in order to determine the sugar yield from each treatment.

Growth measurements and eye spot counts are to be taken until the experiment is harvested in 1929. Eye spot during the summer months will be negligible, but it will be interesting to learn the average number of eye spot lesions per leaf which occur throughout the summer months. A final presentation of all yields, growth measurements, and eye spot counts from each treatment will be made when the test is harvested.

At one time some were of the opinion that heavy applications of potash to fields subject to eye spot lessened the severity of the disease in a marked degree. To date, potash in all experimental work has never shown a definite control of the disease, as determined by eye spot counts. In observation tests where potash has been applied, several still maintain the disease was greatly reduced; these conclusions are merely from observations and not from quantitative measurements.

The experiment with varying amounts of potash in relation to eye spot was put in Field Mill 7, which, in the past, has been affected badly with eye spot. The field contained H 109 second ratoons and the previous crop was last harvested June 1, 1927. From the analysis by the chemistry department of the Experiment Station this particular field was low in potash. The object was to determine if a response could be secured by applying heavier applications of potash than the plantation practice, and also to study the effect of varying amounts of potash on the eye spot disease.

Six repetitions of each treatment were applied to irregular plots averaging .419 of an acre each in size. The treatments were as follows:

Waialua Agri. Co. Exp 8, 1929 Crop.

Field Mill 7

Fertilizer Exp. - To determine the response to varying amounts of Potash.

Cane - H109 2nd Ratoon. Previous crop harvested June 1, 1927.

18 Watercourse plots of irregular size extending from level ditch to level ditch. 2 Plots are across one level ditch. Three plots are single watercourses and 15 are double watercourses.

Area:—

A-Plots = 2.4405

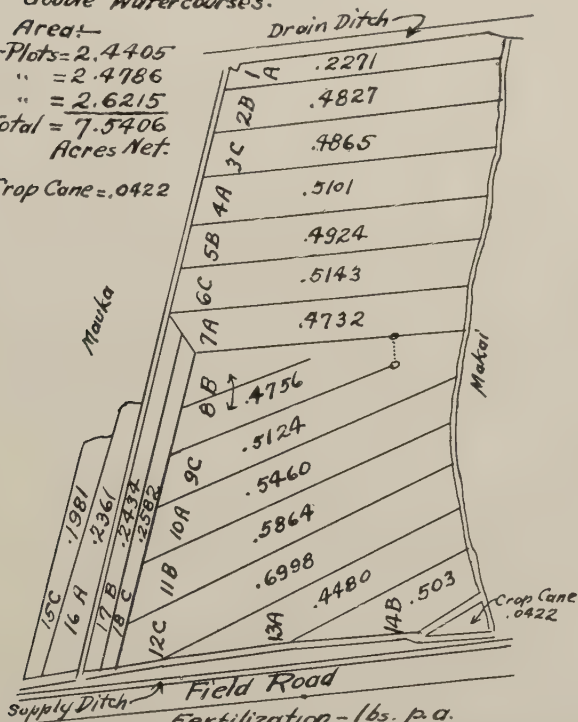
B " = 2.4786

C " = 2.6215

Total = 7.5406

Acres Net.

Crop Cane = .0422



Plots	No. of Plots	1 st Season			2 nd Sea.	Totals		
		Am. Sul. + N. S.	Sup. Phos.	Sul. Pot.	Am. Sul.	N	P ₂ O ₅	K ₂ O
A	6	557	476.2	0	536.6	210	100	0
B	6	557	476.2	200	536.6	210	100	100
C	6	557	476.2	400	536.6	210	100	200

Am. Sul. + N. S. = 18% N₂
 Super Phosphate = 21% P₂O₅
 Sul. of Potash = 50% K₂O
 Amm. Sulphate = 20.5% N₂

Fig. 3

VARYING AMOUNTS OF POTASH IN RELATION TO EYE SPOT

Field, Mill 7, N.A.Co., Ltd.
H 109, first railroads.

	Aug 1927 First Season			March 1928 2 nd Season			Total		
	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
6-A Plots	110	100	0	100	210	100	210	100	100
6-B "	110	100	100	100	210	100	210	100	200
6-C "	110	100	200	100	210	100	210	100	200

Ten growth measurements were taken from each plot or 60 growth measurements per treatment every two weeks. The vertical lines represent the average growth per stalk per treatment. The total number of eye spot lesions were counted every two weeks from 20 leaves per plot or a total of 120 leaves per treatment. The counts were taken on the first fully unfolded leaf on the same marked stalks throughout the experiment. The eye spot curves below represent the average number of lesions per leaf per treatment.

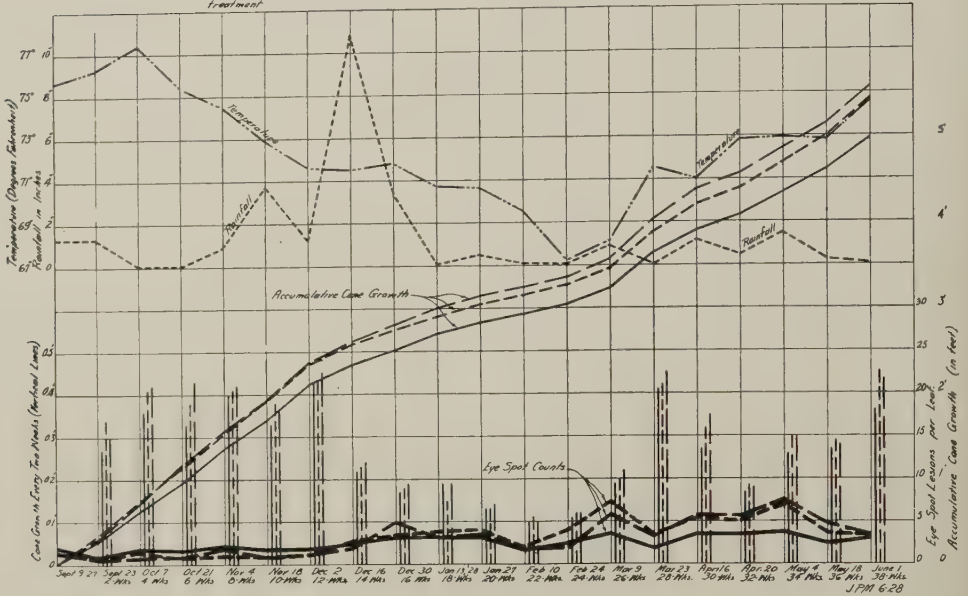


Fig. 4

	July, 1927 1st Season			April, 1928 2nd Season			Total		
	N	K ₂ O	P ₂ O ₅	N	P ₂ O ₅	K ₂ O	N	K ₂ O	P ₂ O ₅
6 A plots	110	0	100	100	210	0	210	0	100
6 B "	110	100	100	100	210	100	210	100	100
6 C "	110	200	100	100	210	200	210	200	100

A detailed plan of the experiment is shown in Fig. 3.

Ten growth measurements were taken from each plot every two weeks, or a total of sixty growth measurements from each treatment at two-week intervals. The cane growth from each treatment is illustrated in Fig. 4. The plots receiving 100 and 200 pounds of K₂O showed a small gain in cane growth when compared to the plots receiving no potash, as brought out in Fig. 4 by the accumulative growth curves. The gain in cane growth from plots receiving 200 pounds of potash per acre over those receiving 100 pounds of potash per acre does not seem to warrant applying an additional 100 pounds of potash in this particular experiment. A small response in cane growth was obtained from the plots treated with potash as compared to the plots that received no potash. A greater difference may be brought out in sugar yields when the experiment is harvested during the 1929 crop.

The number of eye spot lesions on twenty leaves from each plot, or the total number of lesions from 120 leaves, were counted every two weeks from each treatment. In every case the eye spot counts were taken from the first fully unfolded leaf on the same marked stalks throughout the experiment. The average number of infections per leaf is shown in Fig. 4 by the curves labeled "Eye Spot Counts." Very little eye spot occurred in this area during the winter months, as is shown by the eye spot curves in Fig. 4. There was not a sufficient difference in the eye spot counts to draw any conclusions regarding the various treatments of potash in relation to eye spot. Eye spot counts and growth measurements will be recorded in this experiment up to the harvesting period in 1929.

The disease during the previous season was always severe in Field Mill 7, but this past year practically no eye spot infection occurred in this field. It is necessary to put in all experiments well in advance of the eye spot season, and to know the areas subject to the disease. Even then it is possible to have such a light infection that no definite conclusions can be drawn from the various tests.

The final results of this experiment will be presented when the field is harvested.

The control of any disease depends upon the increased yields from plots receiving special treatment over those receiving no special treatment.

In Figs. 2 and 4 the rainfall and temperature for every two weeks during the experiment is plotted. A direct correlation is observed between temperature and cane growth in that with a decrease in temperature there is a decrease in cane growth and vice versa.

Fungicidal Dust Tests Against Eye Spot During the 1927-1928 Eye Spot Season

BY J. P. MARTIN

The results from the experimental research conducted with fungicidal dusts against eye spot during the 1926-1927 eye spot season were sufficiently encouraging to warrant further studies the following season. Two points were established: First, the addition of potassium permanganate as an oxidizing agent at the rate of one per cent to dusting sulphur, gave much better control of the disease when applied at weekly intervals than had been obtained before. Secondly, it was found that when calcium hydrate was used as a carrier the disease increased rapidly and the eye spot counts were greater than those from the check plots or plots receiving no dust treatment. Apparently the calcium hydrate saponified to a large extent the wax on the surface of the cane leaf, thus making it an easy matter for the fungus to penetrate the young cane leaf. It was necessary to discontinue the use of several dusts with a lime base long before the peak of the eye spot season was reached because of the sudden increase of eye spot.

With the above information it was decided to use a fine grade of dusting sulphur as the carrier for all dusts. Since sulphur plus one per cent of potassium permanganate gave such a good control of the disease, it was planned to add other oxidizing agents to sulphur, such as manganese dioxide and lead dioxide.

In fungicidal work "stickers" are often added to dusts and sprays in order that the dusts or liquid sprays may adhere better to the foliage. Upon this basis dextrin and gum tragacanth were added at the rate of one per cent to sulphur plus one per cent of potassium permanganate.

With the above knowledge the following dusts were planned by H. A. Lee and the writer to be tested during the 1927-1928 eye spot season:

Dust No.	Dust Letter	Mixture of Dust	
1	A	Sulphur	
2	B	"	plus 5% KMnO_4
3	C	"	" 1% "
4	D	"	" 5% MnO_2
5	E	"	" 5% PbO_2
6	F	"	" 1% KMnO_4 plus 4% MnO_2
7	G	"	" 1% " " 1% Dextrin
8	H	"	" 1% " + 1% gum tragacanth
2	I	"	" 5% "
3	J	"	" 1% "

In Field Kemoo 1 of the Waialua Agricultural Company, Ltd., which contained young plant H 109 cane, 42 ten-line plots were staked and labeled according to the plan as shown in Fig. 1. Dusts A, B, D, E and F were applied every two weeks, while Dust I was applied weekly, beginning October 28, 1927. There were six repetitions of each fungicidal dust treatment and six check plots that received no treatment. No further dust applications were applied after February 9, 1928, which was after the peak of the eye spot season.

Eye spot counts were taken in each plot from 20 leaves, or the total number of lesions from 120 leaves were counted every two weeks from each treatment. In every case eye spot counts were taken from the first fully unfolded leaf on the same marked stalks throughout the experiment. The average number of eye spot lesions per leaf from each treatment is shown in Fig. 2 by the heavy curves labeled eye spot counts.

The word *control* as used throughout this article signifies the difference for each treatment between the average number of lesions or infections per leaf of the treated and of the non-treated plots. The difference is secured by comparing quantitative calculations as explained in the preceding paragraph. This is not to be confused with the more practical definition of the word *control* as applied to plant diseases which compares the increase in yield of any crop due to special treatment with the yield obtained from similar plots or areas not receiving special treatment.

The object of applying fungicidal dusts to cane is to have a coating of the dust on the leaves at all times during the winter months so that the spores of the fungus upon germination are immediately killed as soon as they come in contact with the dust, thus preventing their entrance to the leaf. Once the fungus has penetrated the leaf a dust or spray that would be toxic to the development of the

organism within the leaf tissue would also be very injurious to the cane plant itself. To maintain such a coating of dust on the cane foliage during the rainy season it would be necessary to apply such dusts to the susceptible areas from two to three times a week. These numerous applications would be prohibitive on a plantation basis because of the expense that would be involved.

The damage on cane leaves resulting from eye spot is not in direct proportion to the number of infections. The seriousness of the disease depends largely on the location of the infections in the leaf itself. From each infection large runners or streaks develop, extending from the initial infection, up the vascular system, to the edge of the leaf. The tissue killed by the so-called runner is oftentimes a hundred times greater than the tissue killed by the primary infection. If ten lesions occur on a single leaf so that ten separate runners are formed, the damage is much greater than if ten lesions occur on another leaf with only five runners formed, due to the fact that certain of the infections fall within the streaks extending from lower infections on the leaf. Therefore, 50 lesions may produce the same amount of damage as 100 lesions.

Ten growth measurements were taken at two-week intervals from each plot, and the average growth per stalk per treatment is presented in Fig. 2 by the vertical lines. The accumulative cane growth from each treatment is also presented in Fig. 2 for the duration of the experiment, which was thirty-eight weeks.

The peak of the eye spot season occurred on January 19, 1928, and the per cent of control from each dust at that date was as follows:

Dust	Per Cent Control
A	31
B	44
D	45
E	41
F	43
I	46

A control with each fungicidal dust was maintained during the eye spot season, as shown in Fig. 2. On January 19, 1928, the lesions per leaf in the dusted plots varied from 128 to 161 as compared to 235 per leaf on the plots receiving no dust treatment. Field observations at this date showed that all plots were badly affected with eye spot, but a fair control was evident on the dusted plots.

The addition of "stickers," such as dextrin and gum tragacanth, did not give an added control of the disease when compared to similar dusts without the "stickers."

In Field Valley 3 of the Waialua Agricultural Company, Ltd., which contained young plant H 109 cane, the remainder of the dusts listed were tested, namely, dusts C, G, H and J, including dust A. In this experiment 42 ten-line plots were staked and labeled according to the plan as shown in Fig. 3. There were seven repetitions of each treatment, and seven check plots which received no dust applications.

Eye spot counts were taken in each plot from 20 leaves, or the total number of lesions from 140 leaves were counted every two weeks from each treatment. The

counts were taken from the first fully unfolded leaf on the same marked stalks throughout the experiment. The results of the various fungicidal dusts A, C, G, H and J, in relation to the control of the disease, are presented in Fig. 4 by the heavy curves labeled eye spot counts.

Ten growth measurements were taken at two-week intervals from each plot and the effect of each dust treatment on the cane growth is shown in Fig. 4, both by the vertical growth curves and the accumulative growth curves.

As illustrated in Fig. 4, a definite control was secured with each fungicidal dust, but no one dust showed exceptional merit. The eye spot counts started to increase rapidly about November 29, 1927, and the peak of the season was reached February 21, 1928. Two other smaller peaks occurred on April 2 and May 1, but the effects of these were negligible. The control from each dust at the peak of the eye spot season, February 21, 1928, was as follows:

Dust	Per Cent Control
J	62
A	55
C	53
G	47
H	47

A decided decrease in the accumulative cane growth was evident on the check plots when compared to the accumulative cane growth from the dusted plots as brought out in Fig. 4. The cane growth on the dusted plots at all times was practically the same. At the end of the experiment, May, 1928, a difference of one foot of cane growth was observed between the dusted plots and non-dusted plots. This difference was due to the high mortality of individual stalks resulting from top rot in the non-dusted plots.

There appears to have been a very good control from all dusts when expressed in terms of per cent. When leaves average 100 or more eye spot lesions per leaf, another 100 lesions does not add greatly to the present damage to the leaf, but there is a great difference in the control as expressed in per cent. Even though a control varying from 47 to 62 per cent was obtained with the various dusts, it would be necessary to keep the average number of lesions or infections below 60 per leaf in the experimental tests before the dust could be used on a commercial basis.

Of the dusts tested, sulphur plus one per cent of potassium permanganate, when applied at weekly intervals, gave the best control of the disease. This particular dust was also the outstanding one during the preceding eye spot season, and at that time an 89 per cent control was secured.

During the winter months frequent rains are common. In view of the experimental evidence it is necessary to apply the dusts at weekly intervals rather than at two-week intervals because a great deal of dust is washed from the foliage by the rains. It is impossible to apply the dusts at certain periods for two weeks at a time, because of daily showers or rains. Under these conditions the fungus spreads rapidly and the efficacy of any dust against eye spot applied during the winter months depends largely on the rainfall.

In Figs. 2 and 4 the rainfall and temperature are plotted every two weeks for the duration of the experiment, and a direct correlation is observed between temperature and cane growth, and also between rainfall and eye spot counts. With a decrease in temperature there is a decrease in cane growth, and with an increase in temperature there is a corresponding increase in cane growth. With an increase of rainfall there is a marked increase in the eye spot counts, and each eye spot peak, whether large or small, is accompanied by an increase in rainfall. These correlations are brought out by referring to Figs. 2 and 4.

SUMMARY

1. Sulphur plus one per cent of potassium permanganate gave the best control of all the dusts tested. This particular dust was the outstanding dust in last year's experimental work (1926-1927).

2. The interval between two-week applications was too great during the rainy weather. Weekly applications of fungicidal dusts should be maintained during the winter months.

3. The efficacy of any dust against eye spot depends largely on the amount of rainfall and the frequency with which the dust is applied during the very wet weather.

4. Before a dust is tested out on a commercial basis, the average eye spot lesions per leaf should be kept below 60 at all times in preliminary experimental test plots.

5. There was a direct correlation between temperature and cane growth; with a decrease in temperature there was a decrease in cane growth, and with an increase in temperature there was an increase in cane growth.

6. There was also a direct correlation between rainfall and eye spot counts; with every sudden increase in eye spot counts there was a corresponding increase in rainfall slightly preceding the increase in the eye spot counts.



Sugar Prices

96° Centrifugals for the Period June 18 to Sept. 15, 1928

Date	Per Pound	Per Ton	Remarks
June 18, 1928.....	4.285	85.70	Porto Ricos, 4.27, 4.30.
“ 19.....	4.32	86.40	Porto Ricos, 4.33; Philippines, 4.31.
“ 22.....	4.30	86.00	Porto Ricos, 4.27; Cubas, 4.33.
“ 26.....	4.3633	87.27	Porto Ricos, 4.33, 4.36; Cubas, 4.40.
“ 27.....	4.36	87.20	Cubas.
July 3.....	4.33	86.60	Philippines.
“ 5.....	4.36	87.20	Cubas.
“ 6.....	4.345	86.90	Cubas, 4.36, 4.33.
“ 10.....	4.255	85.10	Philippines, 4.27; Cubas, 4.24.
“ 11.....	4.21	84.20	Cubas.
“ 16.....	4.2025	84.05	Porto Ricos, 4.21, 4.15; Philippines, 4.18; Cubas, 4.27.
“ 17.....	4.14	82.80	Cubas.
“ 18.....	4.11	82.20	Philippines.
“ 19.....	4.095	81.90	Philippines, 4.11; Porto Ricos, 4.08.
“ 20.....	4.14	82.80	Cubas.
“ 24.....	4.195	83.90	Cubas, 4.18; Porto Ricos, 4.21.
“ 25.....	4.14	82.80	Cubas.
“ 26.....	4.11	82.20	Cubas.
“ 27.....	4.14	82.80	Cubas.
“ 30.....	4.095	81.90	Cubas, 4.11, 4.08.
“ 31.....	4.02	80.40	Cubas.
Aug. 1.....	4.09	81.80	Philippines.
“ 2.....	4.11	82.20	Porto Ricos, 4.08; Cubas, 4.11, 4.14
“ 3.....	4.065	81.30	Philippines, 4.05; Cubas, 4.08.
“ 6.....	4.11	82.20	Cubas.
“ 8.....	4.095	81.90	Cubas, 4.11; Philippines, 4.08.
“ 9.....	4.11	82.20	Porto Ricos.
“ 10.....	4.14	82.80	Cubas.
“ 14.....	4.175	83.50	Cubas, 4.21; Philippines, 4.14.
“ 15.....	4.24	84.80	Cubas, 4.21, 4.27; Philippines, 4.24.
“ 16.....	4.27	85.40	Cubas.
“ 20.....	4.14	82.80	Porto Ricos.
“ 21.....	4.14	82.80	Cubas.
“ 28.....	4.11	82.20	Cubas.
Sept. 10.....	3.975	79.50	Cubas, 3.99, 3.96.
“ 11.....	3.96	79.20	Cubas.
“ 13.....	3.985	79.70	Porto Ricos, 3.98; Philippines, 3.99.
“ 14.....	3.99	79.80	Philippines.

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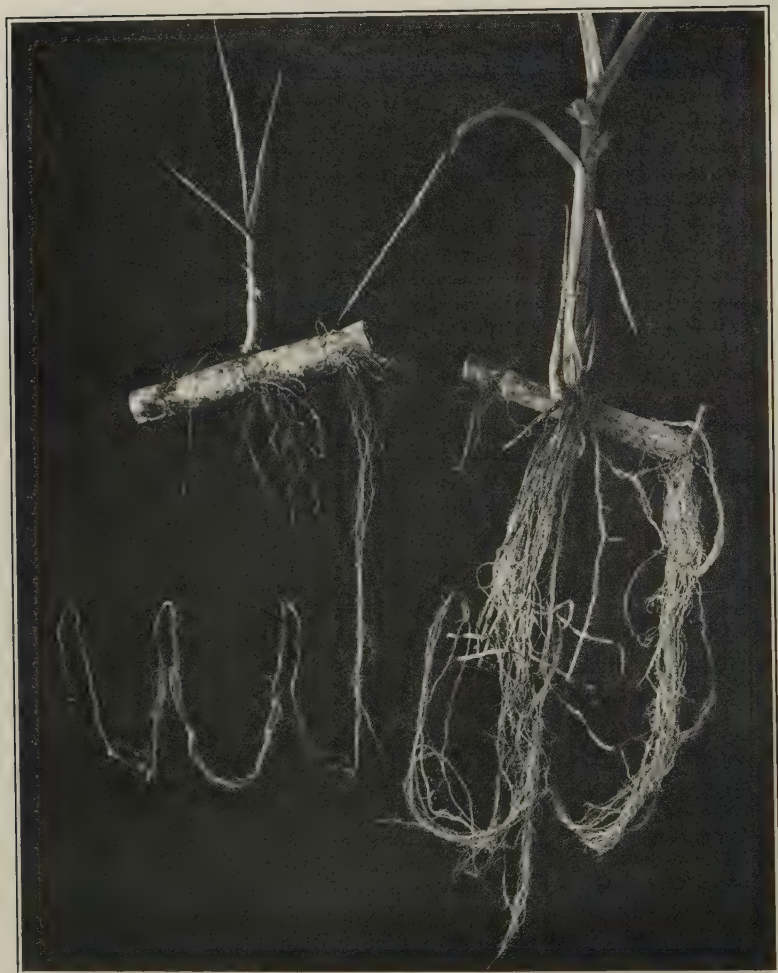
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ILLUSTRATIONS APPEARING ON THE COVERS OF VOLUME XXXII

JANUARY



The poor cane growth on the left was obtained in pot culture in a bad soil. The better specimen is from the same soil after a 20-ton per acre treatment with the molasses-ash-press-cake-bagasse mixture described in this number.

APRIL



P. O. J. 2878

This photograph shows the now famous cane as it appears in the quarantine house at Honolulu at the age of five and a half months.

JULY

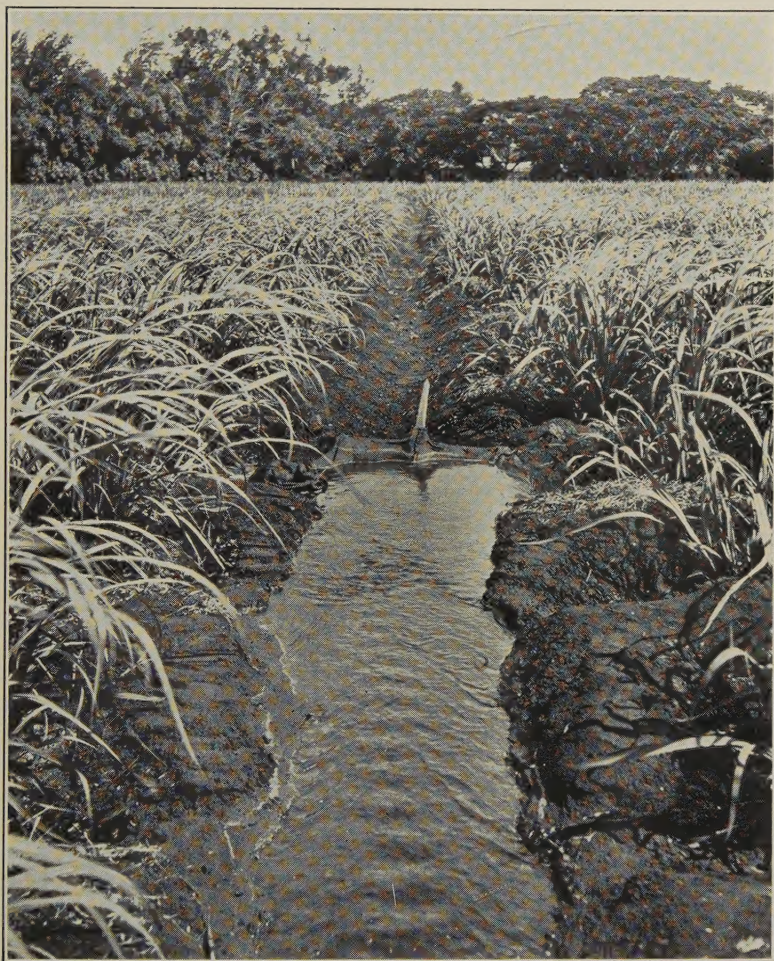


Iron sulphate spray vs. no spray on young ratoon cane affected with lime-induced chlorosis.

Foreground—No spray.

Background—Sprayed twice with 5 per cent solution of iron sulphate.

OCTOBER



As an efficient aid to irrigation, the "Koloa Pani," as used by John T. Moir, Jr., is an extremely promising development.

